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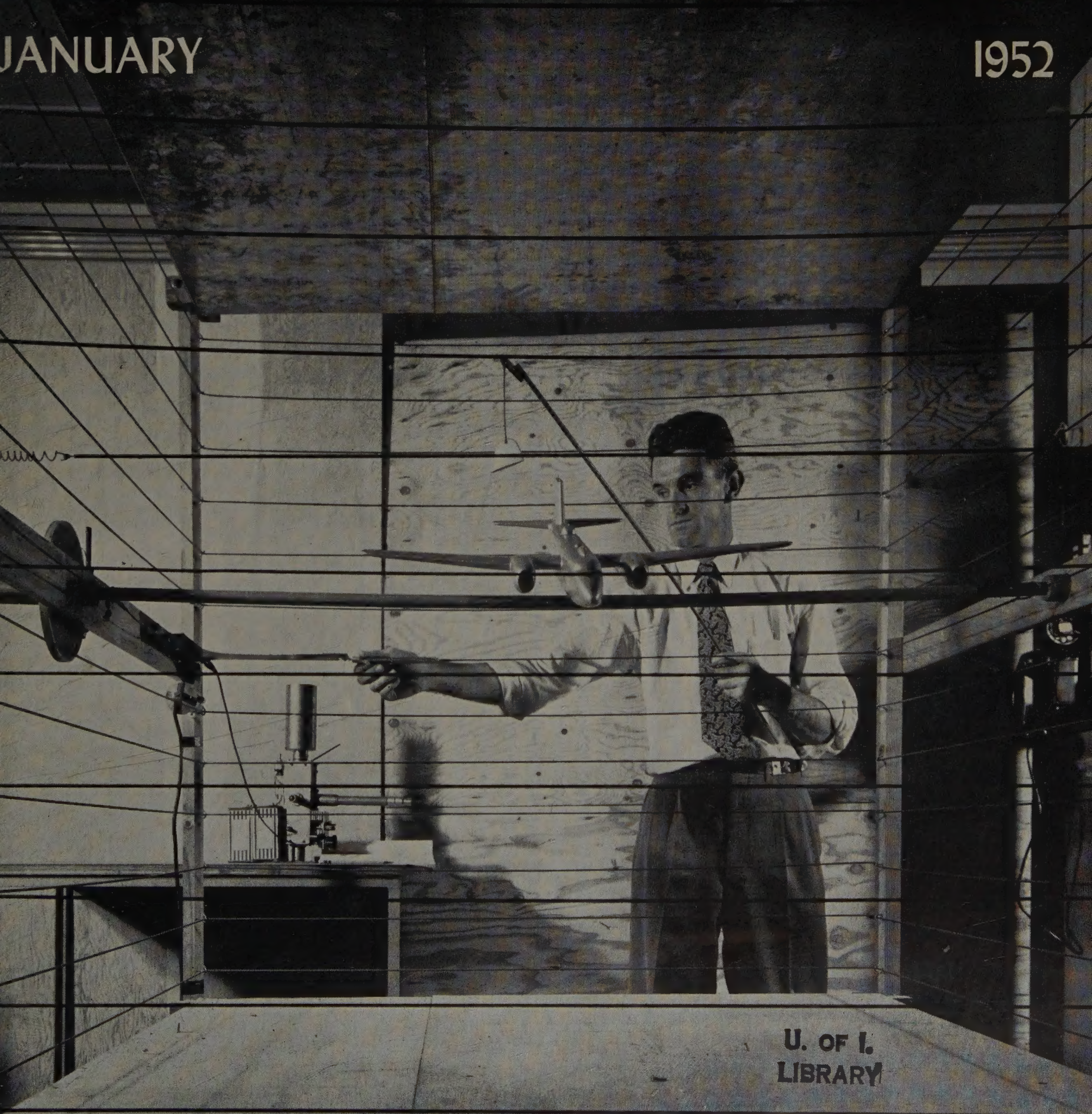
JANUARY 1952



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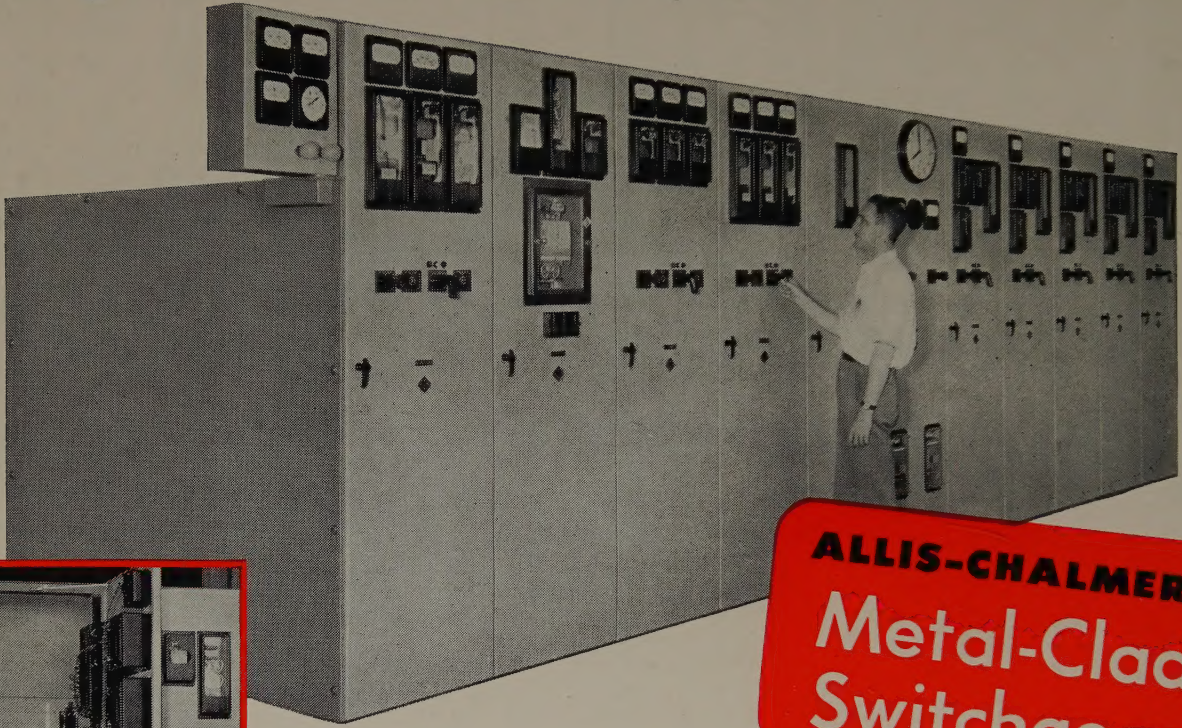
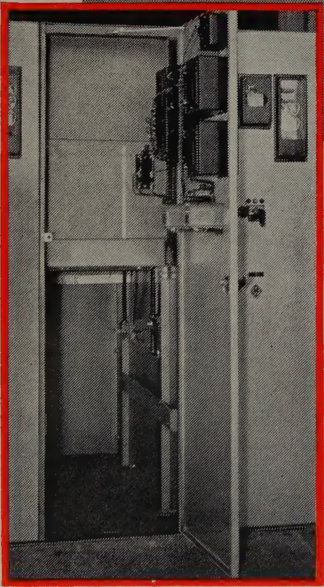
WINTER GENERAL MEETING, NEW YORK, N. Y., JANUARY 21–25, 1952

Better Because of Your Your Operating Experience



ALLIS-CHALMERS
Metal-Clad Switchgear



Welded-in floor plates provide a smooth rolling surface for your circuit breaker. Guide rails placed at each side of the breaker compartment add rigidity to the structure. A-3385

Ruptair is an Allis-Chalmers trademark.

YOU HELPED US design improvements into our switchgear. As the result of your suggestions and operating experiences, we added many new features including more panel space for instruments and relays, welded-in floor plates, wider guide rails, additional protection for wiring and made a more rigid switchgear structure. The new switchgear design is not only more functional, but it's attractive as well. It makes an impressive installation in any plant.

You requested more compartment space for mounting auxiliary equipment. So we designed a new and more spacious compartment for mounting power transformers, transfer bus and similar equipment. It permits you to make a variety of circuit arrangements in a single standard breaker unit.

You wanted to avoid special plant floors for the installation of switchgear. We designed welded-in floor plates to eliminate this requirement and still provide smooth rolling surfaces for the breakers. *Ruptair* magnetic air circuit breaker equipped with built in wheels roll over this steel floor smoothly and easily.

As the result of your experience and suggestions, special wiring is looped where flexing occurs to eliminate excessive wear. Wide full length guide rails on each side of the breaker compartment increase structural rigidity and protect wiring.

Your ideas have helped make standard Allis-Chalmers switchgear safer, stronger and better built. It's modernized to do a better protection job for you.

Standard Allis-Chalmers switchgear is composed of matched units, yet it can be tailor-made to suit your requirements. Get the facts today from your local Allis-Chalmers sales office. Or write direct to Allis-Chalmers, Milwaukee 1, Wisconsin.

ALLIS-CHALMERS

A-C ALLIS-CHALMERS

First in the U. S. with Metal-Clad Switchgear

ELECTRICAL ENGINEERING

Registered United States Patent Office

JANUARY
1952

The Cover: Sensitivity and radiation pattern of aircraft tail-cap antennas are measured in a d-c field configuration at Stanford Research Institute, Stanford, Calif., under U. S. Air Force sponsorship. The d-c field represents a "frozen" instant of the radio-frequency cycle and the charge induced on the tail-cap, proportional to the antenna's receiving sensitivity, is measured on electrometer in background.

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VOL. 71 NO. 1

Statements and opinions given in articles appearing in *ELECTRICAL ENGINEERING* are expressions of contributors, for which the Institute assumes no responsibility. Correspondence is invited on controversial matters.

Published monthly by the

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Founded 1884

Headquarters
33 West 39th Street
New York 18, N. Y.

Editorial Offices
500 Fifth Avenue
New York 36, N. Y

F. O. McMILLAN, President
H. H. HENLINE, Secretary
PUBLICATION COMMITTEE: K. B. McEachron, *Chairman* F. R. Benedict D. T. Braymer H. W. Codding P. B. Garrett L. F. Hickernell Everett S. Lee G. R. Mezger J. R. North T. A. O'Halloran G. C. Quinn C. S. Rich J. D. Tebo G. C. Tenney E. R. Whitehead C. H. Willis

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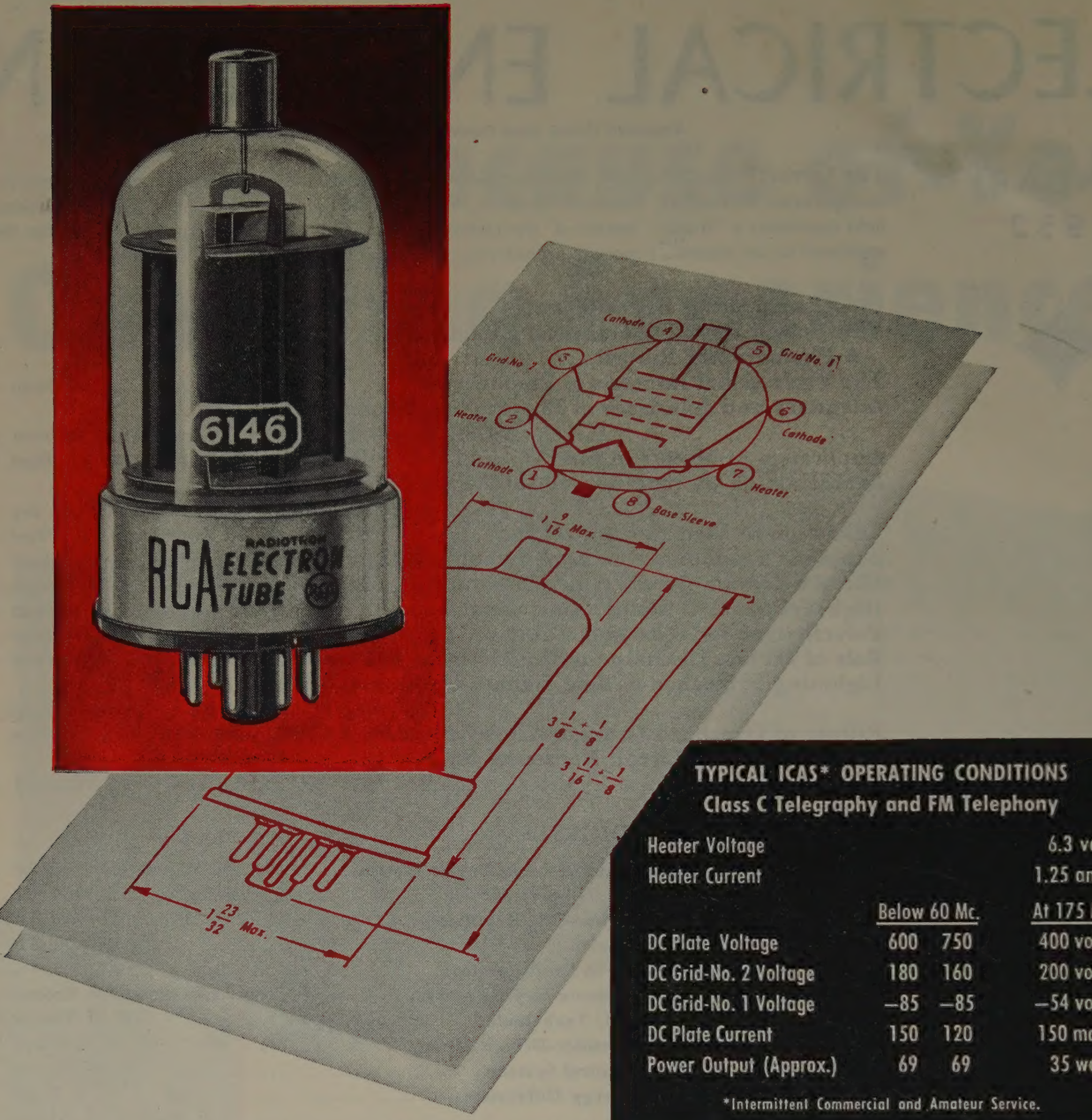

TYPICAL ICAS* OPERATING CONDITIONS
Class C Telegraphy and FM Telephony

	Below 60 Mc.		At 175 Mc.
Heater Voltage			6.3 volts
Heater Current			1.25 amps
DC Plate Voltage	600	750	400 volts
DC Grid-No. 2 Voltage	180	160	200 volts
DC Grid-No. 1 Voltage	−85	−85	−54 volts
DC Plate Current	150	120	150 ma
Power Output (Approx.)	69	69	35 watts

*Intermittent Commercial and Amateur Service.

Another RCA First... the RCA-6146

New beam power tube for VHF transmitters

Specifically designed for VHF transmitter applications, the new RCA-6146 features low cost, small size, unusual ruggedness, and high power sensitivity. It can deliver an output of 35 watts at 175 Mc under ICAS conditions, with a plate voltage of 400V., and a plate current of 150 ma. Adequate driving power can be obtained from a 5763, 2E26, or another 6146, depending upon the circuit design requirements.

The RCA-6146 employs a rugged button-stem construction with short internal leads, and an octal base with short metal sleeve which shields the input to the tube so completely that no other external shielding is required. Input and output circuits are well separated by bringing the plate lead out at the top of the bulb. Base pin connections permit three connections to the cathode, to provide good rf grounding.

For complete technical data on the RCA-6146 and RCA-6159, write RCA, Commercial Engineering, Section 39AR, Harrison, N. J., or your nearest RCA field office.

FIELD OFFICES: (East) Humboldt 5-3900, 415 S. 5th St., Harrison, N. J. (Midwest) Whitehall 4-2900, 589 E. Illinois St., Chicago, Ill. (West) Madison 9-3671, 420 S. San Pedro St., Los Angeles, Calif.

Another **new RCA tube**

The RCA 6159, identical with the 6146 except for its heater rating of 26.5 volts, 0.3 amperes, is designed for VHF service in aircraft application.

The Fountainhead of Modern Tube Development is RCA

RADIO CORPORATION of AMERICA
ELECTRON TUBES ***HARRISON, N. J.***

HIGHLIGHTS........

1951 Index. The 1951 Index to *Electrical Engineering* is being distributed with this issue as Section 2. It is subdivided into subject, author, AIEE and non-AIEE news, and biographical indexes.

1951 Engineering Developments. At the close of each year, the many achievements and developments in the field of electrical engineering of the past 12 months are considered and evaluated. In this issue a picture survey reflecting some of the year's significant engineering developments is presented, and a number of the AIEE technical committees review various outstanding engineering developments of 1951 that fall within their particular scopes (*pages 1–22*).

Professional Interests of Engineers. Aspects of the problem of recognition and unification of the engineering profession are discussed by the author in an attempt to show that a thorough analysis of the problem must be made before a solution can be offered (*pages 23–26*).

Standards of Engineering Education. After evaluating factors in the development of engineering colleges and in their programs, a special committee of the Engineers' Council for Professional Development makes suggestions regarding accrediting, graduate work, and engineering degrees which should do much to improve college programs (*pages 27–30*).

Electric Motors in the Paper Industry. Some of the more important applications of electric motors in the pulp and paper industry are described this month along with data for calculating suitable motor ratings for driving the various types of machines used in the paper-making process (*pages 31–35*).

Manual Methods of Resuscitation. A method of producing apnea by injections of pentothal sodium and curare drugs has been perfected; thus a subject is provided who is unconscious and unable to breath, thereby resembling one who actually requires artificial respiration. With this technique manual methods of resuscitation were applied to 50 adult males (*pages 38–40*).

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Television in Medicine and Biology. One of the most important applications of television outside the entertainment field is the television microscope. This and other related devices, such as cancer cell and red blood cell counting apparatus and equipment for televising operating techniques, are described in this article by RCA's V. K. Zworykin and L. E. Flory (*pages 40–45*).

Benjamin Franklin. This year marks the 200th anniversary of the flying of Benjamin Franklin's famous kite. This experiment in the field of electricity was only one performed by Franklin, and the author has given a short summary of Franklin's electrical achievements (*pages 47–49*).

Selenium Rectifiers in Magnetic Amplifiers. This article points out the ways in which the use of selenium rectifiers in self-saturating magnetic amplifiers differs from other applications. Using two common circuits as illustrations, the effect of circuit configuration on rectifier reverse voltage is indicated (*pages 51–54*).

High-Voltage A-C Motor Controllers. With the greatly increased capacity of today's power systems, both users and manufacturers of a-c motors are becoming more conscious of the need for specifying high interrupting rating for high-voltage motor controllers. The modern trend is toward the use of air-break contactors because of the great reduction in space (*pages 54–57*).

Polyethylene for Wire and Cable. The successful use of polyethylene as a sheath for telephone cable is the result of extensive laboratory testing and field experience. A summary of these tests is given for the purpose of evaluating polyethylene as a material for cable sheath (*pages 59–64*).

Synchronous Motor Starting Performance. A review is presented of the methods used at present for controlling the starting of synchronous motors and a method is proposed in which the user may change the starting performance through the selection of the proper field circuit resistance. The method consists of selecting the motor to meet starting torque requirements and meeting pull-in torque requirements by adjusting the external field resistance (*pages 83–86*).

AIEE Proceedings

Order forms for current AIEE *Proceedings* have been published in *Electrical Engineering* as listed below. Each section of AIEE *Proceedings* contains the full, formal text of a technical program paper, including discussion, if any, as it will appear in the annual volume of AIEE *Transactions.*

AIEE *Proceedings* are an interim membership service, issued in accordance with the revised publication policy that became effective January 1947 (*EE, Dec '46, pp 567–8; Jan '47, pp 82–3*). They are available to AIEE Student members, Affiliates, Associate Members, Members, and Fellows.

All technical papers issued as AIEE *Proceedings* will appear in *Electrical Engineering* in abbreviated form.

Location of Order Forms	Meetings Covered
Mar '51, p 35A	Winter General
Jul '51, p 23A	Southern District North Eastern District Great Lakes District Summer General
Nov '51, p 37A	Pacific General Fall General

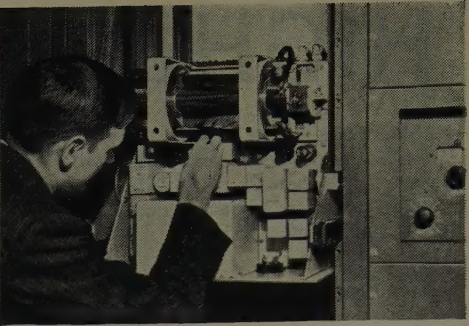
Corona Discharge in Electrical Precipitation. The corona discharge is the most effective way of producing ions for particle charging in such processes as smoke and dust precipitation. A complete discussion of the corona discharge and how it behaves in electric precipitators is presented (*pages 67–73*).

Lightning Protection Report. The AIEE Subcommittee on Mobile Radio presents a report on the protection of base station radio equipment against the lightning hazard. The installations considered are the fixed or land stations communicating with mobile units and operating in the 30- to 300-megacycle band (*pages 73–75*).

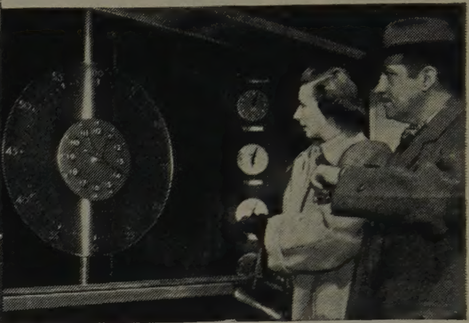
Vibration in Overhead Ground Wires. A comparison is given of the various types of construction used to install overhead ground wire and of the more common methods of avoiding damage by vibration fatigue in transmission lines. These factors must be considered to get the most protection per dollar from the overhead ground wire and to insure satisfactory life (*pages 77–79*).

Membership in the American Institute of Electrical Engineers, including a subscription to this publication, is open to most electrical engineers. Complete information as to the membership grades, qualifications, and fees may be obtained from Mr. H. H. Henline, Secretary, 33 West 39th Street, New York 18, N. Y.

ELECTRICAL ENGINEERING. Published monthly by the American Institute of Electrical Engineers; publication office 20th & Northampton Streets, Easton, Pa. Editorial and advertising offices 500 Fifth Avenue, New York 36, N. Y. Subscription $12 per year plus extra postage charge to all countries to which the second-class postage rate does not apply; single copy $1.50. Entered as second-class matter at the Post Office, Easton, Pa., under the Act of Congress of March 3, 1879. Accepted for mailing at special postage rates provided for in Section 538, P. L. & R. Act of February 28, 1925. January 1952, Vol. 71, No. 1. Number of copies of this issue 53,500

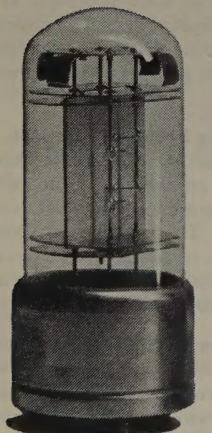


Each crystal is enclosed in a cylindrical oven which holds the crystal temperature to within 1/100 of a degree.



At the A. T. & T. building at 195 Broadway, New York, passersby set watches by the world's most accurate public clock, which is controlled by the master standard.

↑ Front of the new frequency-time standard at Bell Telephone Laboratories. In the rear there are 600 electron tubes and 25,000 soldered connections. Room temperature is maintained within two degrees.



The controlling quartz crystal vibrates in vacuum at 100,000 cycles per second. The standard is powered by storage batteries, with steam turbo-generator standing by, just in case of emergency.

A vibrating crystal keeps master time

Ever since Galileo watched a lamp swinging in the Cathedral of Pisa three centuries ago, steady vibration has provided the practical measure of time. In the 1920s Bell Laboratories physicists proved that the quartz crystal oscillators they had developed to control electrical vibration frequency in your telephone system could pace out time more accurately than ever before.

The Laboratories' latest master standard keeps an electric current vibrating at a frequency that varies only one part in a billion, keeping time to one ten-thousandth second a day.

Through secondary standards, a master oscillator governs the carrier frequencies of the Bell System's ship-to-shore, overseas and mobile radiotelephone services, the coaxial and *Radio-Relay* systems which transmit hundreds of simultaneous conversations, or television. In the northeastern states, it keeps electric clocks on time through check signals supplied to electric light and power companies.

The new standard also provides an independent reference for time measurements made by the U. S. Naval Observatory and the National Bureau of Standards. Thus, world science benefits from a Laboratories development originally aimed at producing more and better telephone service.

BELL TELEPHONE LABORATORIES

Improving telephone service for America provides careers for creative men in scientific and technical fields.

1951 ENGINEERING DEVELOPMENTS

Reviewed by AIEE Technical Committees

NOTWITHSTANDING THE engineering manpower shortage and the national defense program, 1951 marks a year of many engineering developments. Advances in the art have been reported by the technical committees in all five divisions of Institute activities. In the field of communications, the completion of the transcontinental microwave radio-relay system, which was inaugurated during the Japanese Peace Treaty Conference in San Francisco, marks an epoch of engineering progress. In the field of illumination, the amount of light produced in 1950, measured in trillions of lumen-hours, was approximately double that used 5 years before. In the metals industries, there has been an increase in the speed and complexity of modern processing lines. Eastern mining has shown a trend toward increased use of mechanized equipment and the need of technically trained men for maintenance and operation. In the field of power generation, three exclusively gas-turbine stations went into operation for the first time. There is a trend toward larger sized units and if manpower and materials are available the next two years will set an all-time record of expansion. Also the first high-voltage series capacitor at 230 kv in the United States was placed in service at Chehalis, Oreg. In the realm of science and electronics, there has been a multiplicity of electronic applications through the whole gamut of industry: communication, control, power, instrumentation, research, and electrical techniques in medicine and biology. Cobalt 60 as an X-ray source has been employed for the treatment of deep-seated cancer and a synchrotron that produces the most powerful X-ray beam, 70,000,000 volts, ever generated for cancer research has been built.

Communications

COMMUNICATIONS SWITCHING SYSTEMS

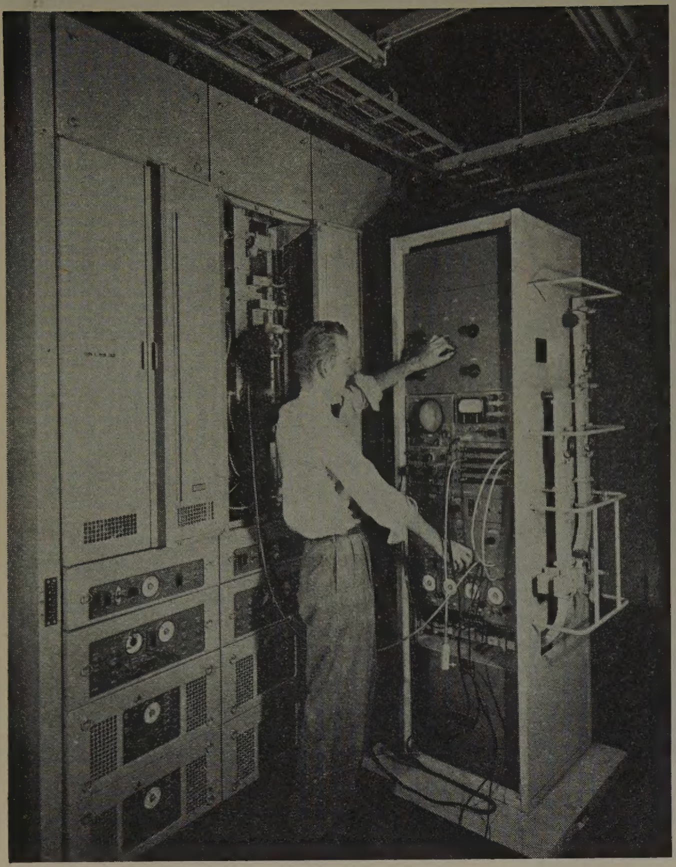
TRANSCONTINENTAL dialing by Bell System customers of long-distance telephone calls was inaugurated on a trial basis on November 10, 1951. In this trial 10,000 telephone users in Englewood, N. J., can dial more than 11,000,000 telephones from coast to coast. The only change from local dialing is that the user must precede the local number with a 3-digit area code used to designate various geographical areas. Switching equipment in the various toll centers then automatically routes the call to the proper local office. Areas which can be reached from Englewood include San Francisco, Sacramento, Oakland, Chicago, Detroit, Cleveland, Pittsburgh, Philadelphia, Boston, and dozens of localities in New York State. Object of the trial is to determine customer reaction and to test under actual conditions the problems involved in automatically connecting such widely separated telephones. Englewood was selected for the trial because the local central office is already equipped with the latest type of dial switching equipment and automatic message accounting devices.

RADIO COMMUNICATIONS SYSTEMS

CONSTRUCTION OF THE final link in the nation's first transcontinental microwave radio-relay system was completed last summer by the American Telephone and Telegraph Company and dedicated to public service in a special ceremony on August 17, 1951, when telephone messages were handled over the system from coast to coast. The system was soon to be used for the first time to bring television pictures to the public over a nation-wide network. The program included President Truman's address to the opening session of the Japanese Peace Treaty Conference in San Francisco and, on succeeding days, similar television net-

Courtesy American Telephone & Telegraph Company

The Buckhorn Mountain relay station, elevation 8,355 feet, is one of the 107 unattended relay stations making up the transcontinental broad-band communication system. The six channels can handle 600 telephone circuits each and also can be used for television transmission. The frequencies employed are from 3,700 to 4,200 megacycles



Courtesy American Telephone & Telegraph Company

The three cabinets at the left are radio transmitter-receiver bays in one of the unattended radio relay stations in the cross-country network. The equipment in each bay will receive, amplify, and transmit one channel in one direction. The test bay at the right is used for locating trouble and routine checking

work transmission of the proceedings of the Conference. Transmission of transcontinental programs in both east- and westbound directions became a commonly accepted service during the last quarter of 1951.

These events mark the climax of a great engineering achievement since the transcontinental system was, by far, the longest broad-band communication system ever built. This system operates on frequencies in the range of 3,700–4,200 megacycles and makes use of 107 unattended relay stations spaced about 30 miles apart. The system is capable of handling a total of 6 broad-band channels in each direction on a single route utilizing a common set of antennas for all six channels. Each such broad-band channel with presently available terminal equipment is capable of handling up to 600 telephone circuits or a television circuit.

The Bell System is rapidly expanding its use of microwave radio-relay systems, its network now including, in addition to the transcontinental system, the New York-Washington, the New York-Boston, the Los Angeles-San Francisco, and the Columbus-Dayton-Indianapolis systems, to mention some of the larger ones. At the close of 1951 there were a total of about 23,000 broad-band channel miles in service in the Bell System, now providing about 400,000 circuit miles of telephone circuits and 14,000 miles of television program circuits.

Microwave radio links and chains of radio-relay stations also have been placed in service by a number of electric power systems, railroads, pipe lines, broadcast and television stations, and telephone companies.

Mobile radio telephones have been serving an increasing number of automobiles, taxicabs, trucks, busses, maintenance cars, railroads, tug boats, and small boats. Radio telephone service for boats on the Great Lakes is now being provided by very-high-frequency channels near 150 megacycles, relieving to some extent the crowded bands between 2 and 9 megacycles.

International radio telegraph systems have been resorting to an increasing extent to multiplex telegraph operation in meeting the demand for more channels in view of the difficult alternative of finding available frequencies for such circuits in the crowded frequency spectrum.

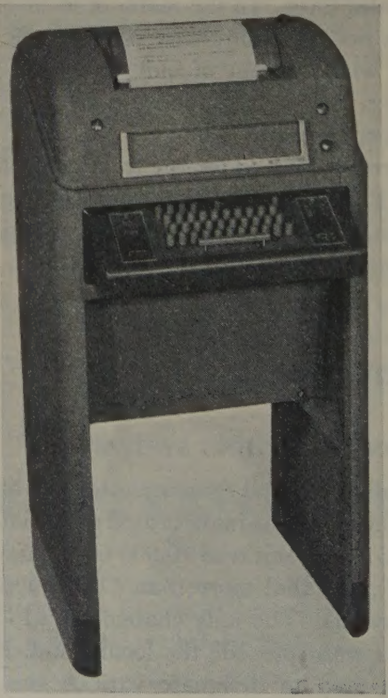
TELEGRAPH SYSTEMS

THE LARGEST LEASED wire system ever assembled was placed in service in February for the United States Air Force (USAF). It comprises five switching centers providing service on a 24-hour basis to 195 drops at 113 locations. Traffic interchanged with their vast overseas radio networks makes the new system an integral part of the world-wide USAF communications system.

A unique page printer is now in production featuring lightness, compactness, fewer parts, higher speed, and extensive application of harmonic motion to rapidly moving parts. Designed for sustained operation at 100 words per minute, it can be geared for lower speeds.

The Teletypesetter has been applied in several networks for transmission of press copy to a chain of newspapers. Copy received on 6-unit code perforated tape is fed to an attachment on the usual type-casting machine, automatically producing cast type for printing.

A new polar relay, the design of which was justified by promise of improved long-term dependability, maintenance-free life, and reduced size and cost has achieved remarkable



Courtesy Teletype Corporation

The Teletype model 28 sending-receiving printing telegraph set

success. Owing to a novel armature and contact mounting it also has shown transmission performance exceeding that of any relay in large-scale use.

A new frequency-shift carrier telegraph system provides up to 19 duplex channels on any 4-wire system having a bandwidth of 2,700 cycles, and features flexibility by being assembled on a unit basis.

In the facsimile field, a new system recently placed in operation for the trunk handling of telegrams is believed to be the highest speed direct-scanning equipment yet announced. It scans at the rate of $2^1/_8$ square inches or 1/4-lineal inch per second. A novel system of loading eliminates any lost time between messages.

An ever-increasing amount of research and development effort on classified military projects dictates that many items worthy of report must be omitted.

TELEVISION AND AURAL BROADCASTING SYSTEMS

The expansion and improvement of television service and programs continued during 1951 through the network interconnection stations. Wide-band television microwave relay circuits were completed between the East and West coasts. The initial program over these facilities permitted the nation to hear and see by television the activity at the meetings and final signing of the peace treaty with Japan in September from San Francisco. The freeze by the Federal Communications Commission (FCC) on the construction of new television stations, in effect since 1948, continued. Power increases were permitted for some existing stations and proposed new rules and standards for new stations were issued which, when finalized, will also open up the frequency band from 470 to 890 megacycles for television broadcasting.

Transmitters and Antennas. The year 1951 witnessed a resurgence of activity in the field of amplitude-modulated broadcast transmitters. The units offered to broadcasters included improvements in operating simplicity, technical performance, and modern styling. Television transmitters in the very-high-frequency bands were designed to provide the increased power permitted by the proposed revised FCC regulations. For the ultrahigh-frequency bands, several manufacturers have developed equipment suitable for the initiation of commercial service. In this connection, klystrons were proposed for commercial broadcasting apparatus for the first time. The development of radiating systems kept pace with the progress on transmitters. High-gain and directional antennas were offered for very-high-frequency television. The stacked antennas on the Empire State building were placed in successful operation, offering considerable promise of alleviating receiver installation problems. Very-high-gain radiators were developed for the ultrahigh-frequency bands permitting adequate coverage to be obtained with reasonable transmitter power output.

Studio Equipment. New developments in aural and visual studio equipment have included more versatile television switching and mixing apparatus, improved television studio lighting equipment and techniques, and the modernization of camera equipment. Progress has been made in the development of color television studio broadcasting equipment, particularly for experimental use in the development laboratories in the field. An example is the color flying spot scanner. There has been continued development in aural broadcasting studio equipment, particularly in the field of sound recording. The dependability and quality of magnetic tape recorders has been much improved during the past year, and this type of apparatus is finding widespread acceptance.

Receivers. The popularity of larger picture tubes increased; by the end of the year nearly all sets produced carried either a 17- or a 20-inch rectangular tube, with a 21-inch tube growing in popularity. The expectation that the FCC will soon release channels in the ultrahigh-frequency region caused manufacturers to develop converters for receiving these new higher frequencies and, in some cases, to make provision in the sets for internal changes to accept the ultrahigh-frequency broadcasts. Total television receiver production was expected to reach about 70 per cent of the 1950 total.

Aural broadcast receiver production continued at a high level. Many manufacturers introduced clock radios, and improvements have been made in personal and portable receivers. A ferrite core loop antenna for amplitude-modulated receivers has permitted improved signal pickup with reduced size; and on frequency-modulated and television receivers progress has continued in reducing oscillator radiation.

WIRE COMMUNICATIONS SYSTEMS

Submerged telephone and telegraph repeaters are new departures which have permitted and will continue to permit increasing the telephone and telegraph circuit capacities very considerably.

N-type carrier is a new system providing the cost and flexibility advantage of carrier in cables for the relatively short-haul light-route field where the older systems are seldom economical.

The *500*-type telephone subset offers substantial advantages in effective loop losses and better quality transmission for future telephone users.

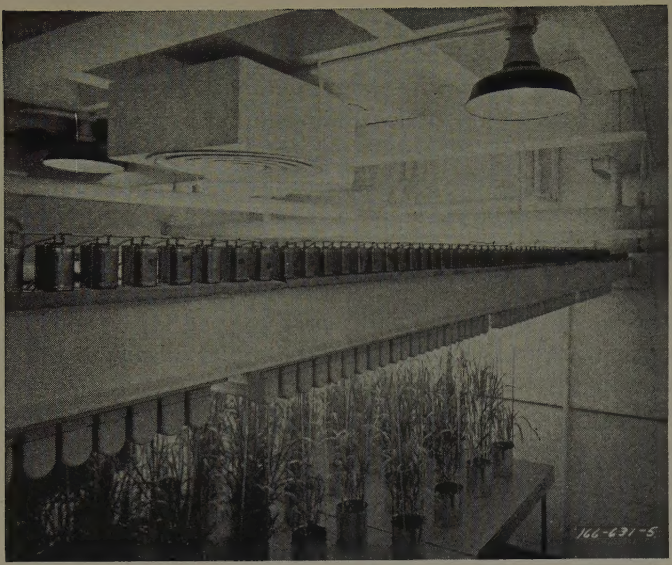
Network transmission of field sequential color television signals first took place on a large scale in 1951.

General Applications

PRODUCTION AND APPLICATION OF LIGHT

The production and application of light has expanded rapidly in the last few years. During 1951 figures were released, based on United States Department of Commerce reports, which showed that the amount of light produced and used in 1950, measured in trillions of lumen-hours, was approximately double the total light used five years before.

During the past year there were constant improvements in light sources of all kinds to increase their efficiency and usefulness. These developments involved more than the light source itself, as in the case of the fluorescent lamp where progress included new types of ballast circuits to give savings in critical materials with desirable starting and operating



Courtesy United States Department of Agriculture

Growing plants under controlled conditions is made possible by using fluorescent lamps, which operate at 360 cycles. This allows the lamps to be controlled by small capacitors with one-tenth the weight, one-twentieth the size, and one-seventh the wattage loss of 60-cycle ballasts

characteristics; new circuits for operating on frequencies higher than 60 cycles, and so forth. A practical demonstration of these developments was made by the United States Department of Agriculture at Beltsville, Md., where fluorescent lamps operate at 360 cycles which allows the lamps to be controlled by small capacitors with one-tenth the weight, one-twentieth the size, and one-seventh the wattage loss of 60-cycle ballasts.

The advances during the year in the application of light were many. In street lighting many large installations of well-engineered incandescent systems were made around the country and progress was made in the use of mercury and fluorescent systems. New applications in industrial lighting ranged from large-scale industrial inspection with ultraviolet radiation through many developments in lighting factories and processes to a number of new uses of infrared radiation in industrial and military fields. The installation during the year of a number of luminous ceilings in offices was a significant step in this field, the ceiling being a translucent plastic lighted by fluorescent lamps above it.

Of particular significance this past year have been the studies concerning the selection of circuit and lamp designs to conserve critical materials, as reported at the AIEE Fall General Meeting. Such economic studies are extremely valuable and are especially important at the present time.

LAND TRANSPORTATION

A series of developments denoting unusual activity in land transportation has centered particularly on the locomotive, rapid transit systems, and the trolley coach. Additional broad fields of endeavor include fuel and energy economy studies, power supply and distribution, and the future aspects of electification and dieselization.

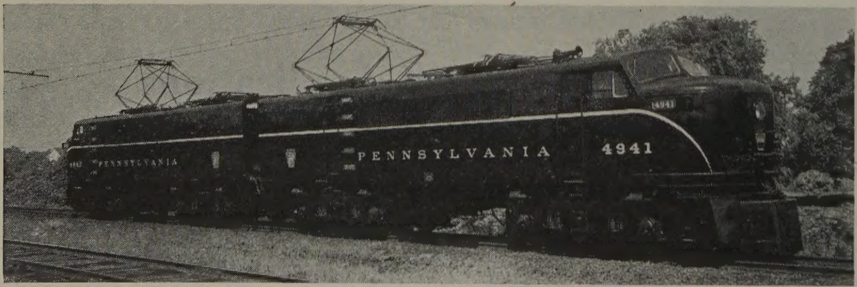
Currently, the electric locomotive is of utmost interest. Simplicity and reliability are the keynotes of design of the two new single-phase, a-c locomotives constructed for the Pennsylvania Railroad. Continued and intensive developments in perfecting the ignitron rectifier for power and industrial fields have revived interest in its use for railway work. Two ignitron-rectifier locomotives also have been built for the Pennsylvania Railroad.

In the foreign field, the French have undertaken a huge experimental and development program to determine the operating economies and benefits of a 50-cycle 20-kv locomotive. Two representatives of the Land Transportation Committee accepted invitations to attend a 4-day conference and demonstration of the locomotive last October. Their reports will be given at the 1952 Winter General Meeting.

Development continues on the diesel-electric locomotive and the gas-turbine locomotive, the Union Pacific Railroad having recently purchased a fleet of gas-turbine units.

Development in wheel-slip protection has been active during the past year.

Our cities are bursting with traffic. Recent rapid transit developments, including electrically propelled rolling stock, have occurred at Chicago, Toronto, Boston, and Cleveland. Several other large cities are studying rapid transit to cope with the intensified traffic movement. All

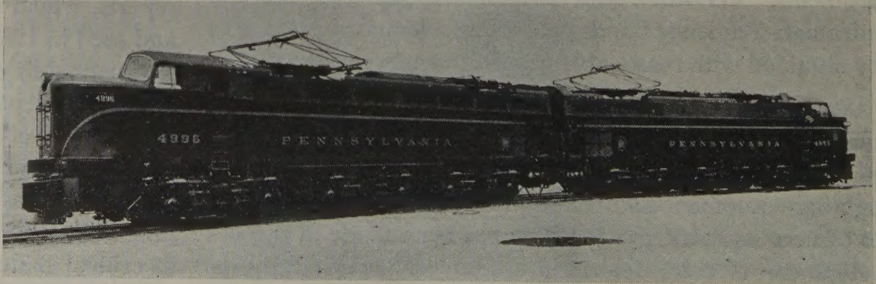


Courtesy General Electric Company

▲ Electric locomotive built for the Pennsylvania Railroad: 240 tons, 11,000 volts a-c, single phase

▼ Ignitron locomotive, 6,000 horsepower, 11,000 volts, 25 cycles a-c, built for the Pennsylvania Railroad

Courtesy Westinghouse Electric Corporation



of the rapid transit installations have been responsible for considerable new electrical development in equipment and for power distribution.

The trolley coach field continues to grow as evidenced by the development effort centered on a new series motor and a new control system. Approximately 9,000 trolley coaches are now operating in Canada and the United States.

Industry

ELECTRIC WELDING

THE MAJOR DEVELOPMENT of the year in electric welding has been in the field of equipment. Introducing metallic rectifiers into the output of 3-phase a-c arc and resistance welding transformers has produced a source for d-c power that has no moving parts and is comparatively inexpensive. An innovation in process as well as equipment has been the mash-seam welder, which welds a lap seam, and finishes it by rolling in such a way that the seam is only slightly thicker than the stock material, and requires no further finishing work in many cases.

Much progress has been made in the use of shielded inert gas metal arc processes, both in the use of tungsten electrode type and the consumable electrode type. Thoriated tungsten electrodes, or the use of other easily ionized additives, have made the arcs from the refractory electrodes more stable. Techniques for elimination of entrapped gases in weld beads on high-conductivity materials of the copper and copper-bearing alloy types have done much to eliminate porosity and produce satisfactory welds in these materials when using the "sigma" process.

The process of low-temperature stress relieving, while not in itself an electric welding process, is associated closely with electric welding. It uses a low-temperature localized heating followed by a quenching action to reduce the stresses in welded seams by redistributing the localized high stresses over a much larger area, thus reducing their magnitude.

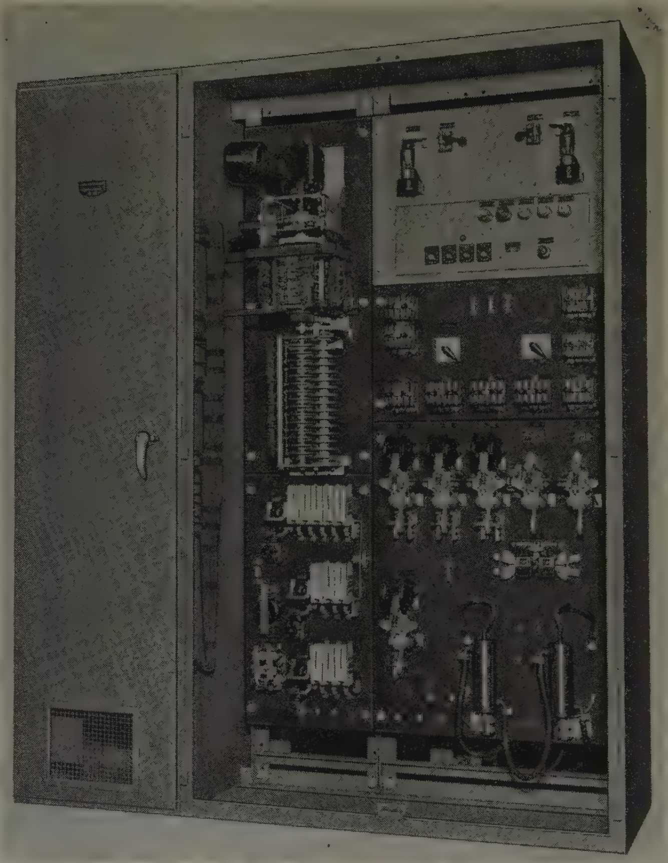
INDUSTRIAL CONTROL

A NEW HEAVY-DUTY, all-magnetic, dynamic-braking lowering crane-hoist control has been developed for series d-c motors with brakes for operation on constant voltage d-c systems. Improved operation with fewer contactors is provided to include low-speed operation on first point in each direction, high-speed hoisting and lowering of a light hook, and stable lowering of heavy loads.

A new line of type-*M* heavy-duty d-c contactors designed specifically for service in steel mill and crane applications was announced during the year. The contactors feature unit construction and are available in National Electrical Manufacturers Association ratings. Silicone-impregnated high-temperature coils permit lower coil inductance and faster operation.

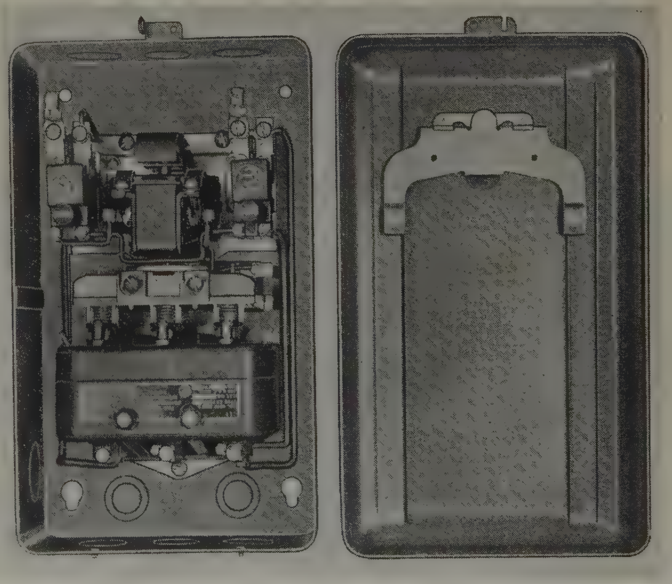
A simple adjustable voltage d-c drive for winches and hoists was developed in unit construction using a minimum of rotating machines and control devices. The superior operating characteristics are high-speed hoisting and lowering of light loads, slower speeds with heavy loads both

(*Continued on page 16*)



Courtesy Cutler-Hammer, Inc.

Controller for single a-c motor printing press with the threading speed obtained electronically. A new secondary resistance regulator offers conventional control with 90 speed points in the operating range. Other features are dynamic braking and a 3-position load switch



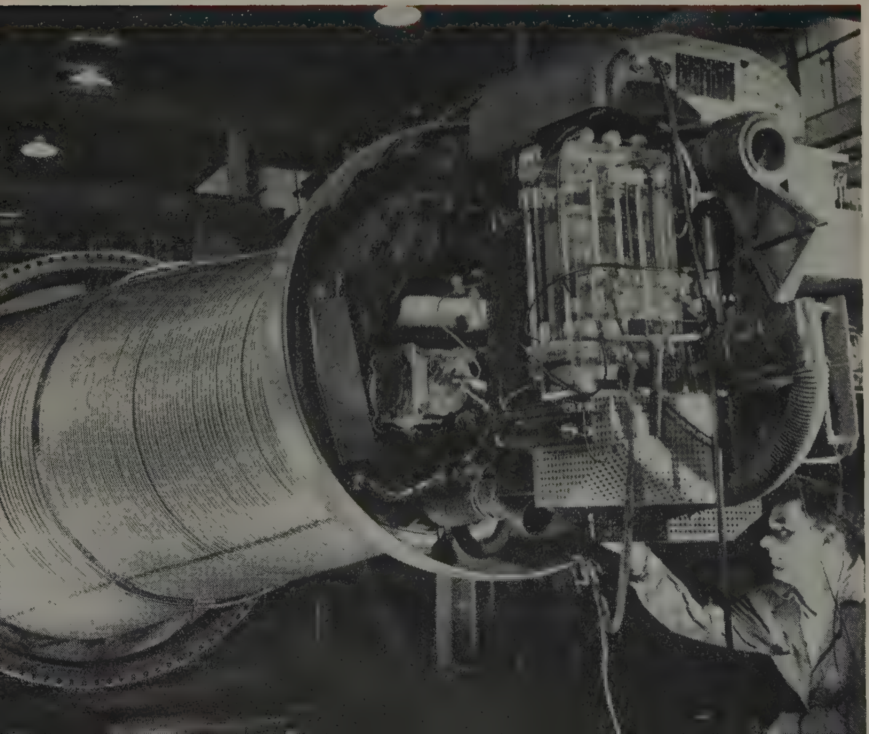
Courtesy Clark Controller Company

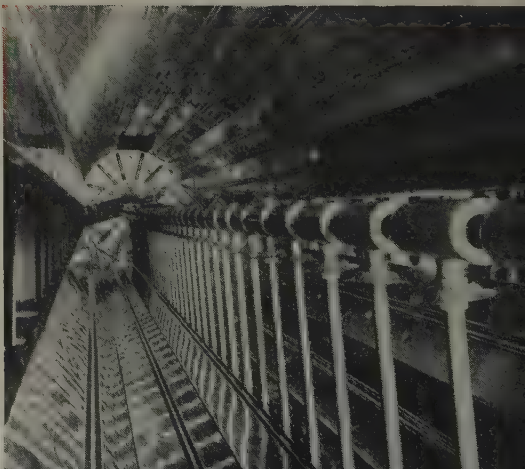
A new principle of arc quenching is incorporated in this line of across-the-line motor starters. Strong multiturn magnetic blowouts are combined with twin break contacts in economical space. The arc in its forced rotation is lengthened or confined and constantly forced to a relatively cool spot on the contacts which results in a minimum of burning and pitting

1951 ENGINEERING DEVELOPMENTS

Photo above courtesy the Aluminum Association

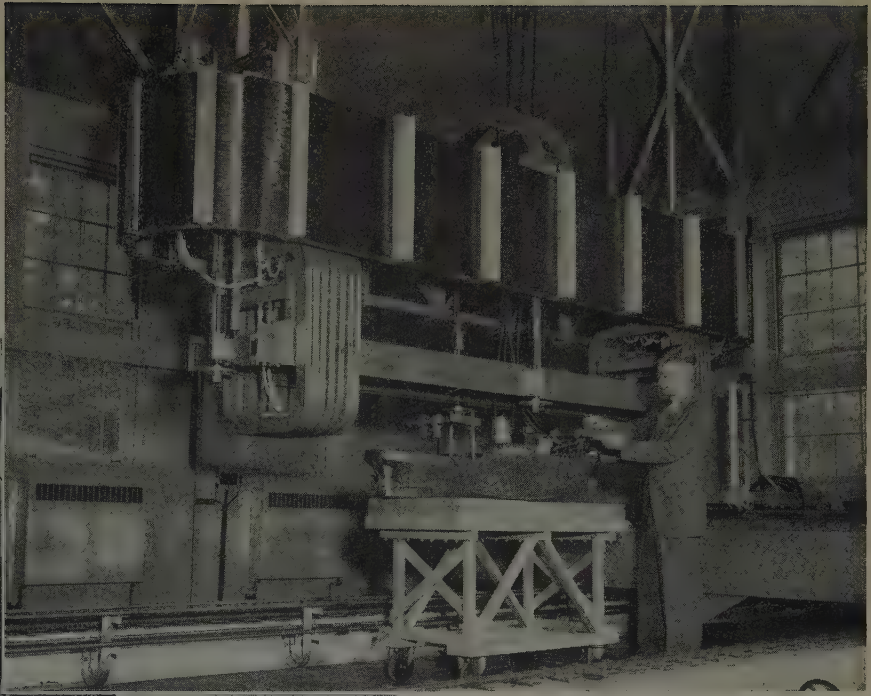
A Photographic Record of Some of the Important Electrical Engineering Achievements of the Year





The end of the Van de Graaf linear accelerator 710 is shown at the left and its liner is shown above. This instrument is in the Radiation Laboratory at the University of California, Berkeley, Calif.

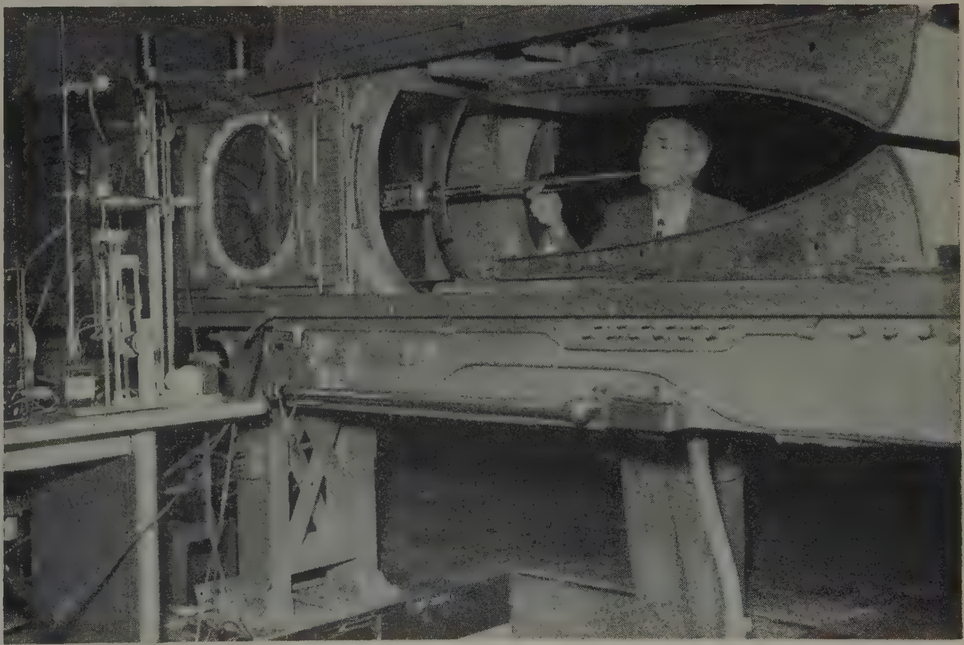
◀ **The 600-inch aluminum reflector on the roof of one of the Naval Research Laboratory buildings will be used for receiving radiant energies emanating from the sun, moon, and planets in the Navy's study of long-range weather forecasting. This new parabolic reflector is made up of pie-shaped aluminum sections which are 2 inches thick and is capable of concentrating the sun's emanations into a beam only a few minutes wide**



The Magnetic Ship Models Building is equipped to simulate any magnetic fields which would be encountered by an actual ship and it can also be used to study an area free of magnetic influences. On the left is shown the master control console in the ship model laboratory where the operator is adjusting the locking mechanism for the transverse carriage in the apparatus shown above

Photos on this page courtesy of Naval Ordnance Laboratory

▼**A sinusoidal instead of a sawtooth scan is used in this trace converter for reproducing electric signals recorded as lines on paper tape, which is scanned by a pinpoint of light reflected from a vibrating mirror**

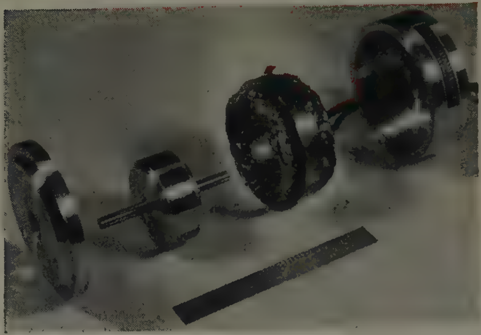


▲**The determination of integrated aerodynamic friction drag on small models in wind tunnels is made possible by use of the axial force balance, developed by the Naval Ordnance Laboratory and shown to the left of the semicircular strip. The axial force investigations have provided important information on friction drag and Reynolds numbers of boundary layer transition on typical supersonic shapes. The basis of the accurate measurement is a pair of linear variable differential transformers**

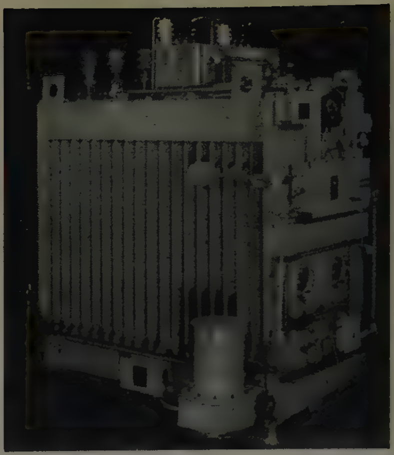
Power

Courtesy Allis-Chalmers Manufacturing Company

▲One of the largest dry-type transformers ever built: 12,500 kva, 60 cycles, 13,200 delta 4,160 Y. It is designed as three single-phase units which make one 3-phase transformer with each phase in its own case

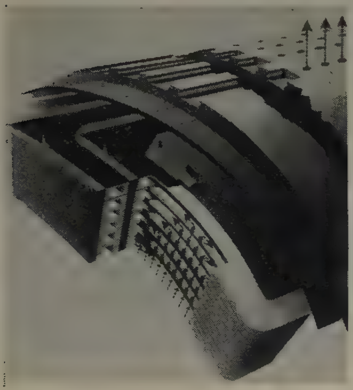


▲New 100-watt permanent-magnet a-c generator developed for the Wright Air Development Center operates at 12,000 rpm, 800 cycles, with a voltage regulation of ±10 per cent over total load range. It is 4 inches in diameter, $1^3/_4$ inches long, and weighs $2^1/_2$ pounds

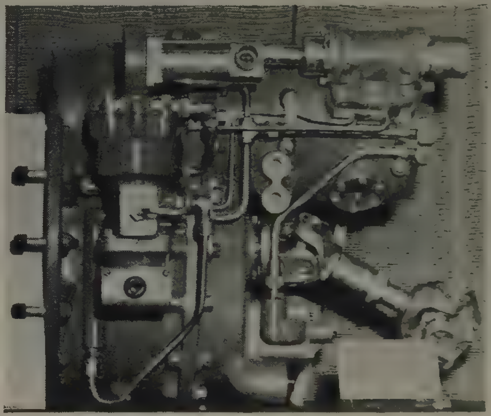


Courtesy Westinghouse Electric Corporation

▲Prototype of 500-kva vaporization-cooled transformer; liquid fluorocarbon is sprayed over core and coils where it evaporates, then cools and insulates these parts

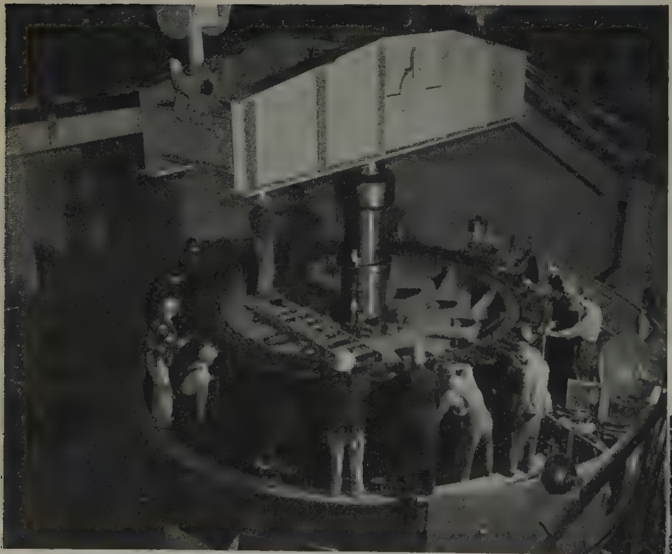


◀By blowing high-pressure hydrogen gas through specially constructed hollow generator rotor coils at high velocity, ratings can be increased by one-half. This Westinghouse development is applicable to turbine generators having ratings of 90,000 kw and above. The phantom view of the rotor shows the path of the hydrogen gas flowing through the rotor conductors



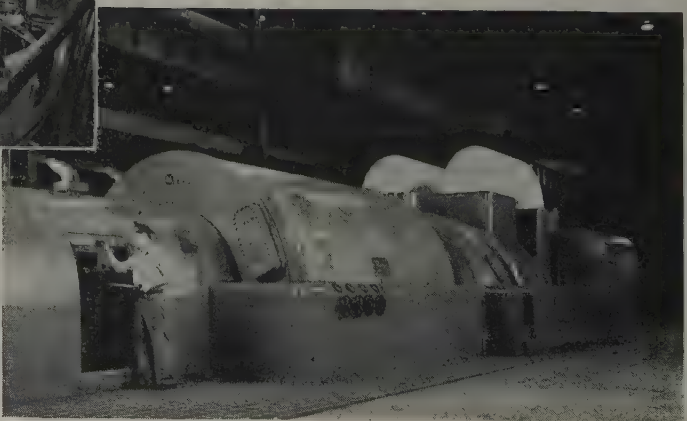
Courtesy Wright Air Development Center

▲This constant-speed alternator drive rated at 60 kva receives variable speed power from an aircraft's power plant, 2,800 to 8,500 rpm, and delivers constant speed of 6,000 rpm to the 3-phase 400-cycle generator



▲Installing the rotor of the world's largest motor, 330 tons and 65,000 horsepower. This is one of two General Electric Company motors in the new pumping plant at Grand Coulee Dam and each one is capable of supplying enough water to meet New York City's daily requirements

▼In addition to the normal cooling fans, a 2-stage compressor mounted at one end of the rotor shaft forces hydrogen over the surfaces of the rotor conductors in this new 60,000-kw 12,500-volt 3,600-rpm generator built by Allis-Chalmers Manufacturing Company for the Wisconsin Power and Light Company. Supercharged cooling increases the subtransient reactance and improves efficiency

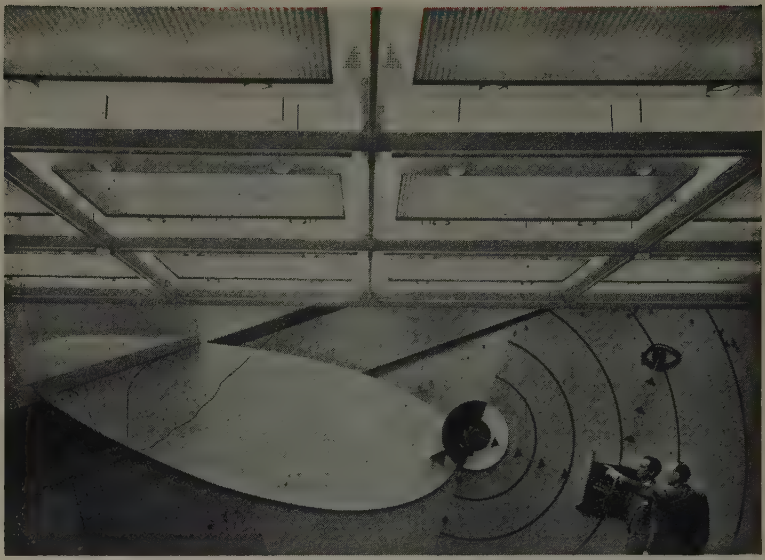


Lighting

▲Light is emitted only from the bottom of this new type industrial lamp with built-in reflector, designed to be burned base up. Within an 80-degree cone, downward candlepower is 4,000 for the 500-watt lamp and 6,000 for the 750-watt size

▶Beside directing two main beams of light up and down a runway, the one-piece 360-degree glass lens provides "off-runway" light for circling guidance. The light uses a 200-watt 6.6-ampere prefocus aviation Westinghouse lamp and can be used with colored filters

▼A basically new light source, the 400-watt fluorescent mercury-vapor lamp provides a light white enough for industrial purposes. This Westinghouse lamp is coated inside with a phosphor that fluoresces red when activated by the ultraviolet light from the quartz arc

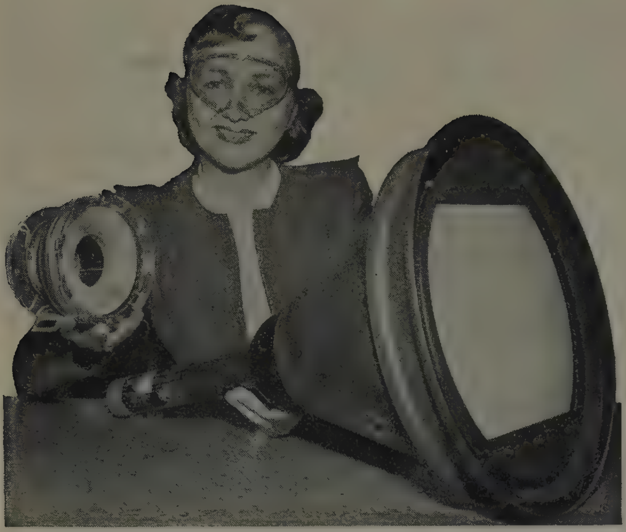


▲This mural in the General Electric Lighting Institute, Cleveland, serves as a decoration and a means of illustrating the elements of seeing. With the light source in the circle reflection is demonstrated to the right following the arrows to the eye and refraction to the left through the triangular prism

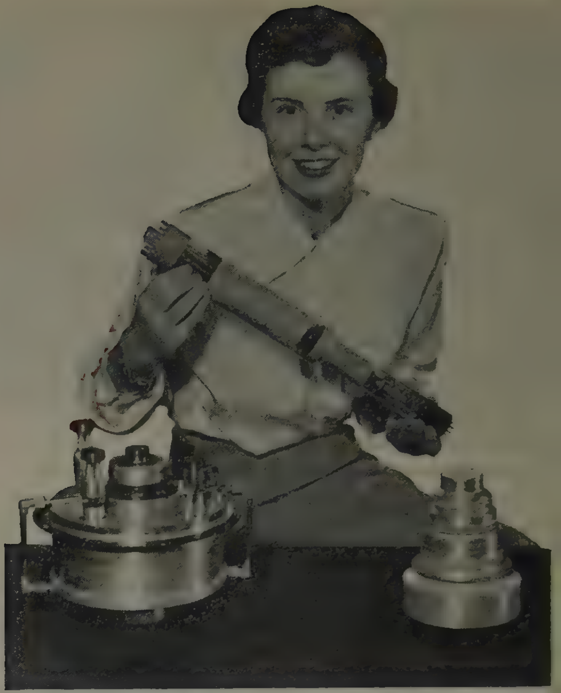
▲Although this 400-watt mercury-vapor lamp was designed to operate base up, it can be used horizontally now due to a magnet, developed by the General Electric Company, which holds the arc approximately centered

▲A new source of light is illustrated by this "panelescent" ceiling, consisting of squares of conductive glass coated with a combination of a light-producing phosphor-dielectric film and vaporized aluminum with wires connected to the edges of the sheet to pick up 110 volts a-c. This was developed by Sylvania Electric Products, Inc.

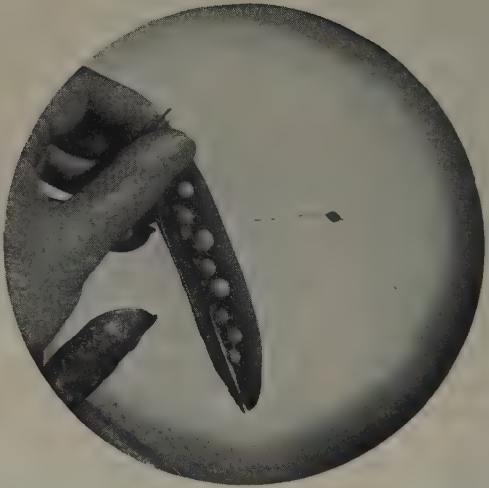
Tubes



▲The heart of the all-electronic tricolor television system, developed by Radio Corporation of America (RCA), is the 16-inch kinescope shown above with the developmental deflecting yoke. Each of the three electron guns in this tube activates its own color-dot field on the tube's phosphor screen

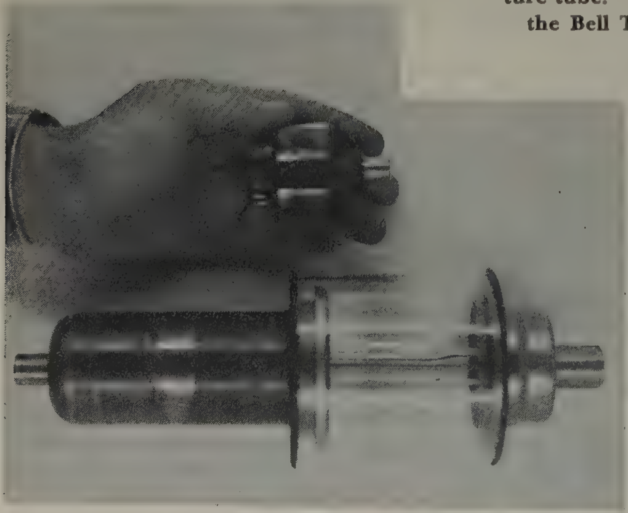


▲The left tube on the table is a 10-kw water-cooled transmitter type for use in the proposed ultrahigh-frequency television band and the tube on the right is a 1-kw air-cooled type for the same band. The third tube, a developmental version of the RCA Graphecon, enables a radar operator to receive a radar pattern at one scanning speed and to reproduce it at another scanning speed

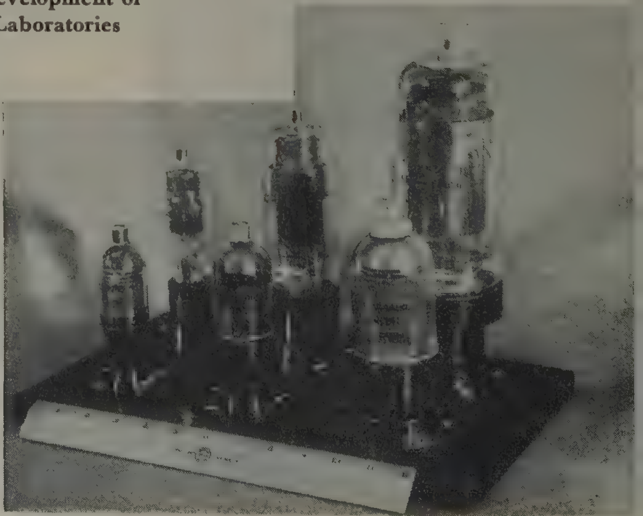


▲The junction-type germanium transistor rivals vacuum-tube performance. It can amplify signals about 100,000 times, requiring about a millionth of the power of a miniature tube. This is a development of the Bell Telephone Laboratories

▼Two high-voltage oil-immersed rectifiers were developed by Westinghouse Electric Corporation. The upper one shown is a 40-kv peak inverse-voltage tube with 900 milliamperes peak current for air-borne radar use. The lower tube provides 125 kv peak inverse for heavy dust precipitation equipment



▼In the rear row are mercury thyratrons and in the front are corresponding xenon-filled thyratrons developed by Westinghouse. Ratings are 1.6, 3.2, and 6.4 amperes average current and inverse-voltage rating of xenon tubes is 1,500 volts; for mercury, 2,500

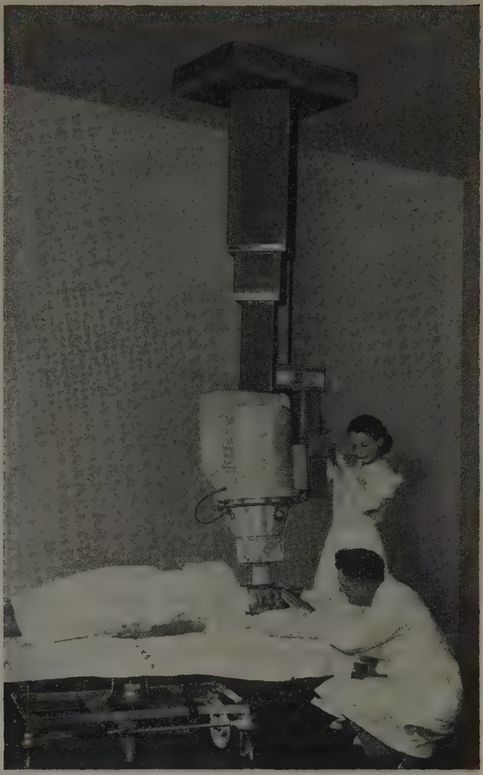


Research

Courtesy Brookhaven National Laboratory

▲To measure the energies of radioisotopes, a sample is placed on top of the photoelectric tube held in the physicist's right hand and the rays emitted by the radioisotope are measured in the electronic equipment at the right, which includes a cathode-ray oscilloscope. The resulting screen patterns are photographed on the Polaroid camera

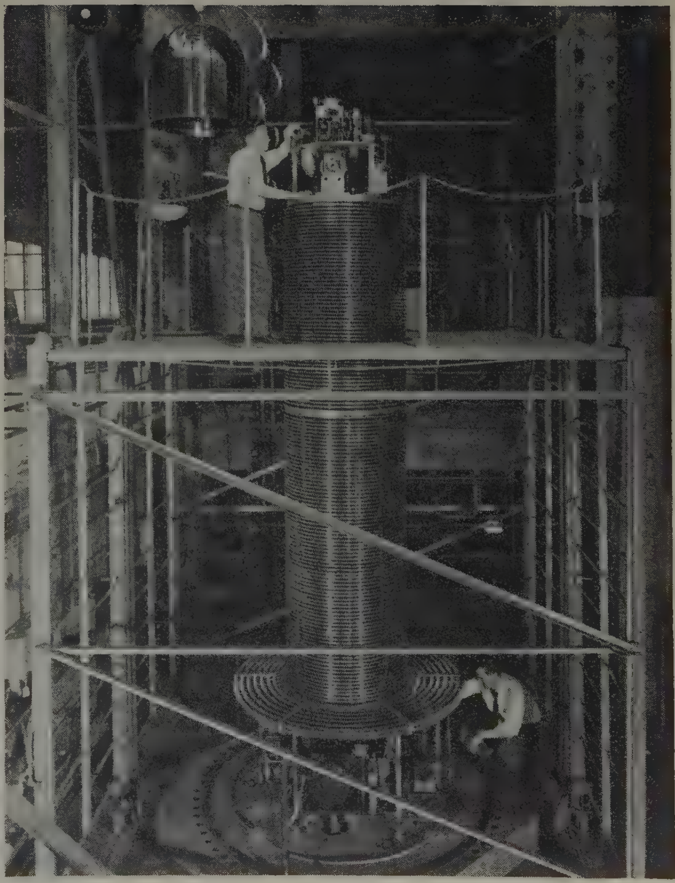
▶Instead of an X-ray tube this new General Electric teletherapy unit uses four small wafers of radioactive cobalt 60 in the head which is only one foot in diameter and is made of Hevimet, a tungsten alloy



▲One of the improvements added to SEAC, the National Bureau of Standards Eastern Automatic Computer, is a high-speed auxiliary memory unit using magnetic tape as the recording medium. Two of these units are shown at the right. Tape inertia is kept low by letting each end fall into the glass tank, which has speeded up the whole memory process

Courtesy Carbide and Carbon Chemicals Company

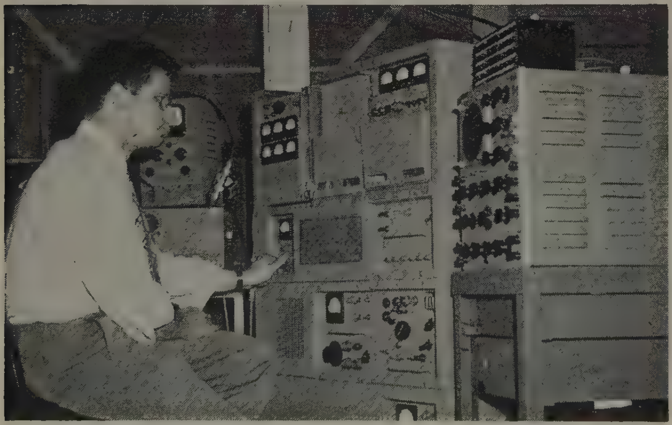
▶The 5,000,000-volt Van de Graaf generator used by the Oak Ridge National Laboratory operates under a pressure of 250 pounds per square inch; its accelerator tube is 12 feet long and the machine's generator tank weighs 19 tons, is 8 feet in diameter at the bottom and wider at the top



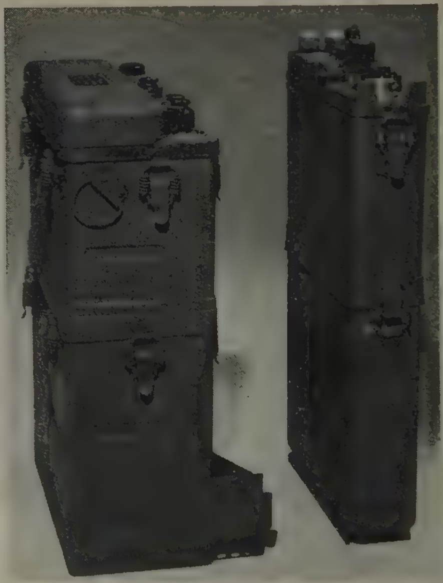
Communication

▲ An "electrical telephone directory" like the one being assembled by the Bell Telephone Laboratories engineer was used in the new long-distance dialing trials from Englewood, N. J. This maze of wires through the coils converts an equipment number into a subscriber's telephone number so that proper charges can be made

A new high-speed facsimile Western Union machine handles copy up to $8^1/_2$ by 15 inches at a speed of 3,000 words per minute. Copy is placed in the plastic cylinder of the transmitter at the right and is scanned through the plastic wall. The recorder at the left using Teledeltos paper receives the message, cuts it off the paper roll, and ejects it. This equipment is part of the intercity radio beam system



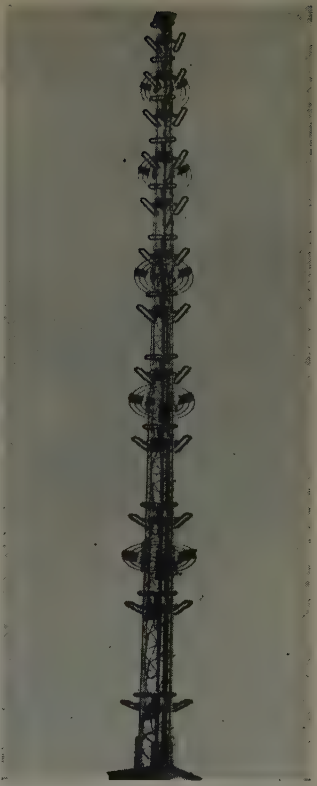
▶ The new walkie-talkie (right) is about one-half the weight of the model used in World War II. Two-way radiotelephone conversation over 5 miles with this battery - operated transmitter and receiver is possible. A whip antenna and handset are not shown



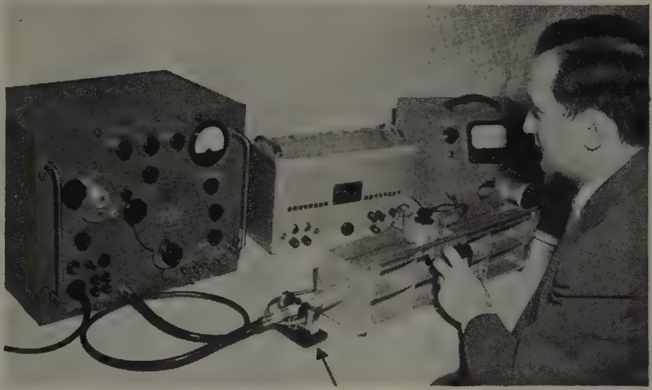
▲ The high-frequency 1-kw single-side-band transmitter shown above was developed at Stanford Research Institute for the Signal Corps Engineering Laboratories. It features automatic tuning of all circuits, permitting frequency change in less than 1 minute

◀ Messages are flashed automatically by pushing a button to any one of 200 telegraph stations in the United States at the United States Air Force's high-speed message center. The network was designed and provided by the Western Union Telegraph Company

▶ A new high-band television antenna has been developed by the Federal Telecommunication Laboratories, Inc. Each loop (three folded dipoles) can handle 1 kw of power. The 12-bay antenna, shown at the right, has a power gain of 11.8, equivalent to 10.7 decibels, over that of a half-wave dipole in a horizontal direction

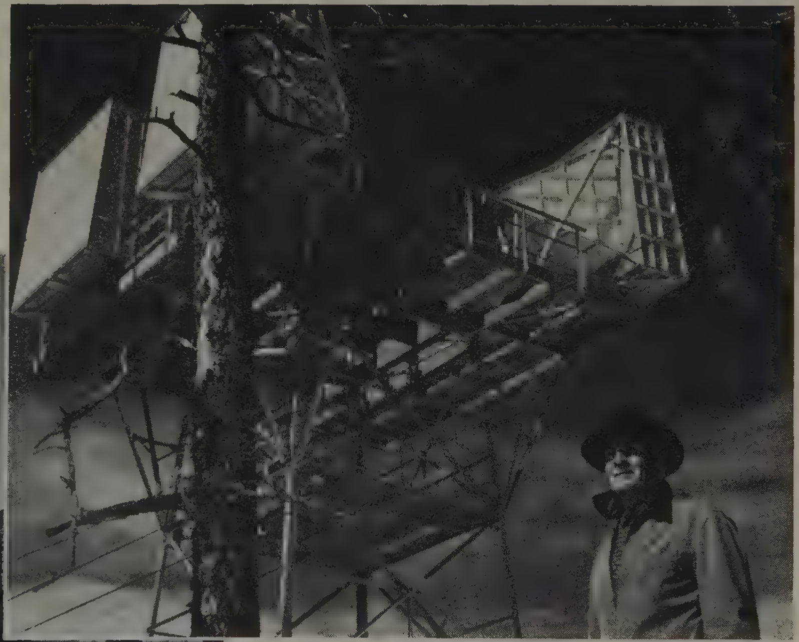


▲ The world's leading medical men at the Paris International Congress of Surgeons watched the operating technique of Dr. Marcel Thalheimer by means of a Columbia Broadcasting System color television pickup in the operating theatre of the Boucicaut Hospital



◀ Utilizing a magnetic field to obtain instantaneous changes in attenuation, the Bureau of Standards developed the microwave attenuator shown by the arrow. It is used to adjust power levels, isolate monitoring equipment, or pad an oscillator

▼ This developmental battery-operated camera and back-pack television transmitter was made possible by the Radio Corporation of America Vidicon television camera tube. Mounted on the top of this 53-pound pack are the antennas for transmitting video signals and receiving instructions from a base station. The range is about 1 mile



▲ Typical antenna system which forms a transcontinental microwave-radio link which can be employed for telephone messages and television signals. There are 107 relay stations in this $40,000,000 system, which functions on a frequency of 4,000 megacycles, designed by the Bell Telephone Laboratories, Inc.

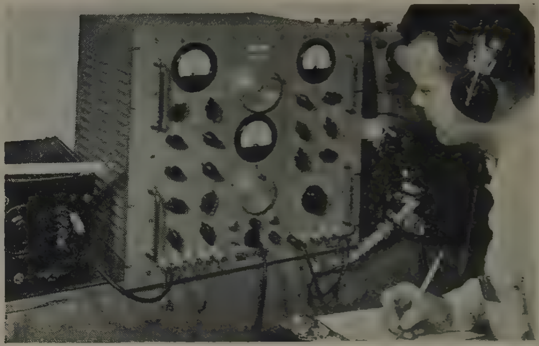
Testing

▲As sliver or yarn runs between the two rolls of the weight tester, variation in thickness causes the top roll to move up or down. This movement is converted into an electric impulse by a General Electric magnetic displacement gauge and inked on graph paper by the photoelectric recorder

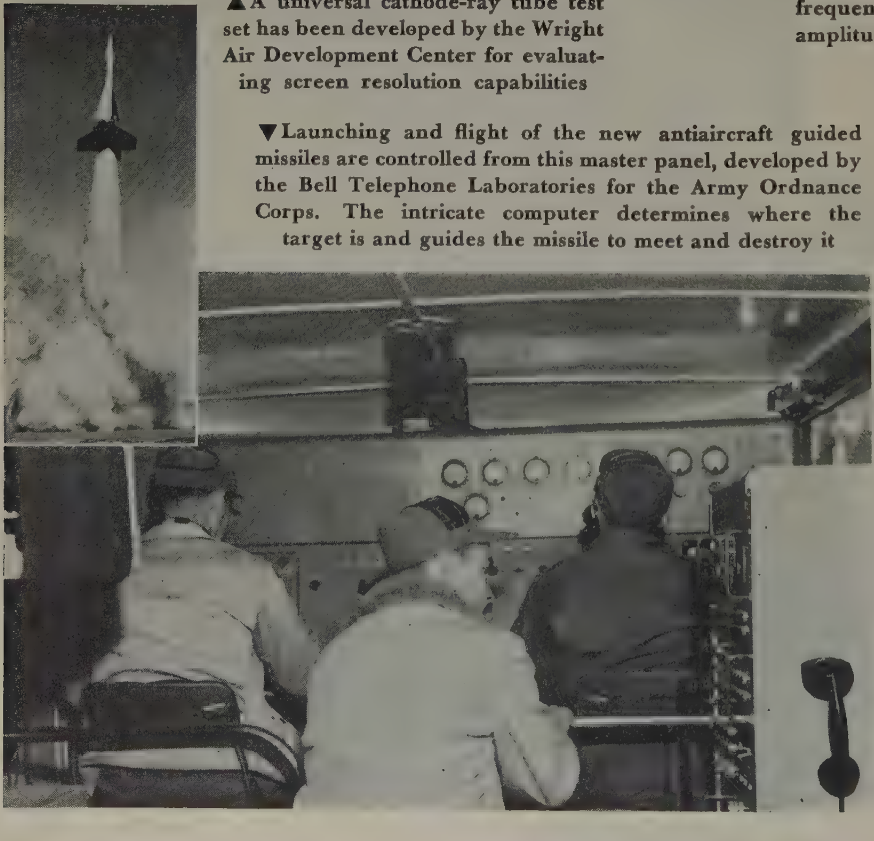
Courtesy Westinghouse Electric Corporation

▲The many components controlling a d-c aircraft generator have been brought together on one panel. Dimensions are standardized and connections are made through a multiterminal plug, making them easily replaceable

▲A universal cathode-ray tube test set has been developed by the Wright Air Development Center for evaluating screen resolution capabilities

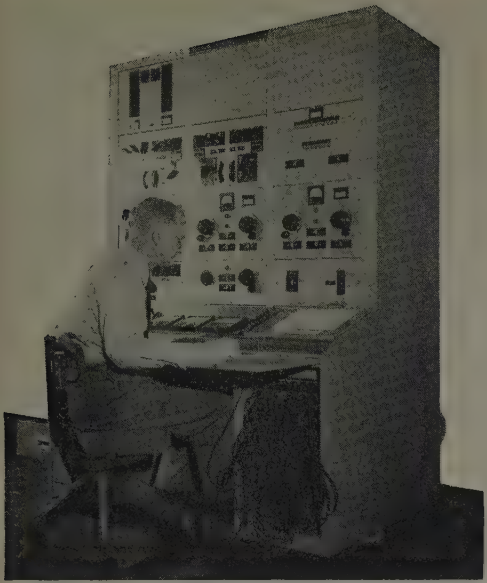


▲A new ultrahigh-frequency signal generator developed at the Wright Air Development Center has a frequency accuracy of 0.001 per cent and provides amplitude-, pulse-, and frequency-modulated output



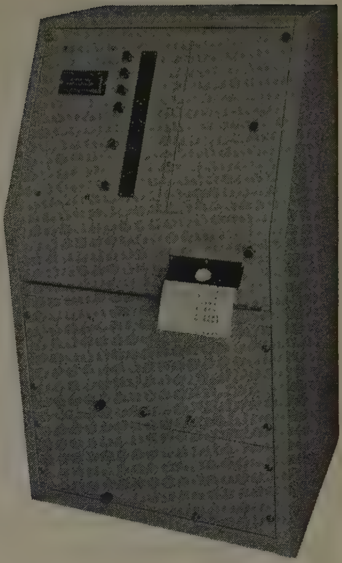
▼Launching and flight of the new antiaircraft guided missiles are controlled from this master panel, developed by the Bell Telephone Laboratories for the Army Ordnance Corps. The intricate computer determines where the target is and guides the missile to meet and destroy it

▲Cables for United States Air Force airborne radar equipment must withstand temperatures between −65 and +135 degrees Fahrenheit. Butyl-insulated cable is tested in the General Electric cold room



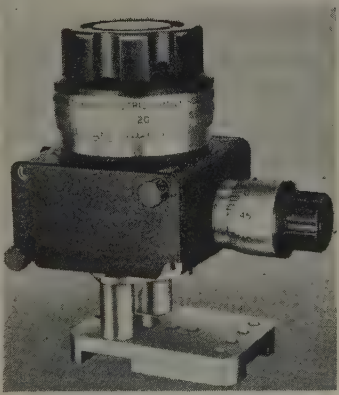
▲A $2^1/_2$-ounce exposure meter has been designed by General Electric primarily for use with color film. A photovoltaic cell is used

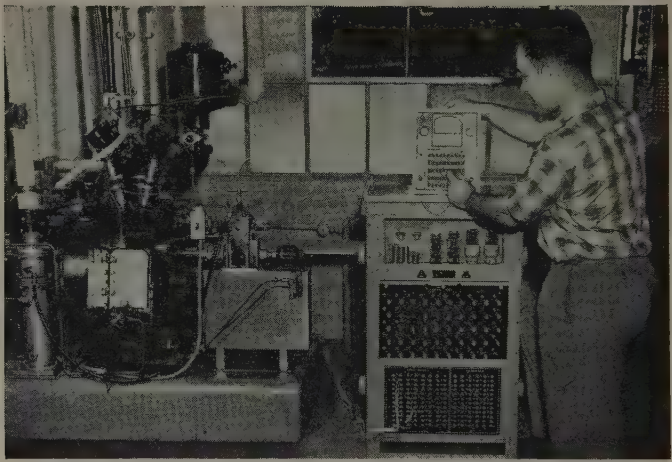
▶This new fault locator utilizes fault - generated surges to locate nonsustained faults on power lines. Designed by Federal Telecommunication Laboratories, Inc. Tests with Bonneville's 200-mile pulse-time modulation microwave system indicate faults can be located to the nearest tower



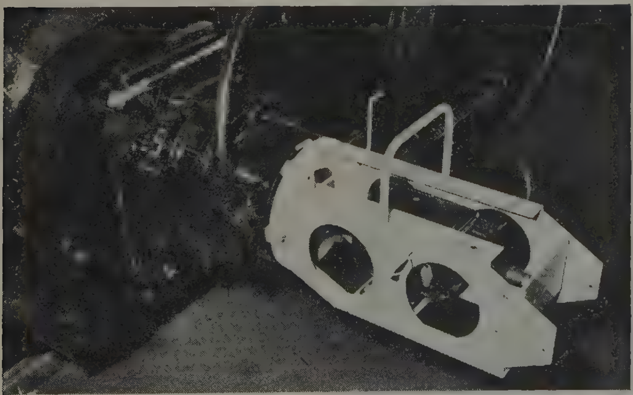
▲With this analogue computer the performance of a proposed design of fractional-horsepower, single-phase motors can be checked in less than a day instead of about a week. This Westinghouse computer, named the MONECA (MOtor-NEtwork-CAlculator), can show the effect of changing one variable better than building two machines and testing them

▶The sample holder for solid dielectric samples, developed by the General Radio Company, eliminates lead impedance by combining the measuring capacitor and electrode system and using a substitution method of measurement. It is used in measuring dissipation factor up to 30 megacycles and dielectric constants up to several hundred megacycles





▲A 48-point temperature monitor was developed at the Bureau of Standards to watch over temperature-critical points in machinery. If the temperature at any one of the 48 thermocouples rises above a predetermined value, an alarm is sounded and a signal lights on the control panel. The temperature of each of the 48 points is checked every 5 seconds and any one may be read on the meter without disturbing the scanning of the other thermocouples



▲Equipment consisting of a portable axle-generator drive unit and a tachometer-frequency indicator has been developed by the General Electric Company for testing the operation of speed-sensitive devices and setting automatic-transition relays and overspeed relays; it checks speedometer accuracy and the sequence of contactors and speed-sensitive relays

▲Photoelectric scanning of fluorescent indications has been developed by the Battelle Memorial Institute and the Magnaflux Corporation. A revolving mirror in the optical system scans the specimen and the detector is a photoemissive type of phototube containing an electron multiplier. Equipment detects small amounts of fluorescent material

1951 ENGINEERING DEVELOPMENTS

(*Continued from page 5*)

hoisting and lowering, flat speed regulation on the first point in both directions, and smooth acceleration and deceleration.

A Load-O-Matic control system has been developed for a-c operated crane hoists which incorporates speed and load detection and saturable reactor primary control to obtain exceptional operating performance. Features are low light hook speeds in the hoisting direction, dynamic braking upon power failure, stable slow speeds for lowering heavy or light loads with heavy loads handled slower than light loads, and an automatic load limiter.

A new Magamp control system has been designed for d-c adjustable voltage tandem cold reduction mills. Two-stage magnetic amplifier regulators for direct excitation of the main generator are incorporated. The use of a 400-cycle source provides extremely fast response in which critical system damping is obtained without damping in the main regulator loop.

An improved liquid slip regulator for motors up to 10,000 horsepower has been developed for use with flywheel motor-generator sets or wound-rotor motors with fly wheels. The equipment includes a new compact liquid rheostat in which the electrolyte is circulated continuously between the cells and a heat exchanger.

A new electronic regulating system has been developed for d-c adjustable voltage dynamometers for precision testing of automobiles, tractors, and their engines, transmissions, and axles.

MINING AND METAL INDUSTRY

Metal Industries. The most significant development in the field of the metal industries is the increase in speed and complexity of modern processing lines such as pickling lines, cleaning lines, side trimming and slitting lines, tinning lines, and galvanizing lines. As an example, the speed of side trimming lines has jumped from less than 2,000 to over 3,000 feet per minute, electrolytic tinning lines are being put into operation for an excess of 2,000 feet per minute, and cleaning line speeds have jumped to almost 2,500 feet per minute. The problem of motor and control co-ordination has increased considerably as the speed has increased. The low speeds required for threading, welding, and changes from one reel to another have remained practically the same even with the increase in top speed. This means that the drive must operate successfully over a much wider range. Furthermore, the increased use of equipment such as edge regulators and the speed and voltage regulators needed for more precise control has increased the need for closer co-ordination between motor and control.

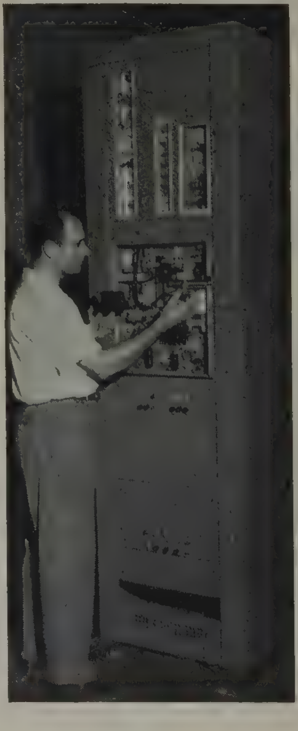
Western Mining. The most significant developments in the field of Western mining are improved communications, introduction of automatic current-limiting dynamic braking for mine locomotives, and large increased use of power because of mechanization. Communication has been improved by the use of mobile radio in open pit mines and by increased use of trolleyphones on mine locomotives. The trolleyphones use carrier current through trolley wire and rail from which the mine locomotive receives d-c power.

Eastern Mining. The most significant development in the field of Eastern mining has been the increasing recognition by the coal mining industry of the need for technically trained men to maintain and operate the machinery required by the rapidly expanding use of mechanized mining equipment, and also the need to develop means for supply and distributing power required by this machinery. The program of mechanized mining is causing a growing need for electrical and other engineers in the mining industry. One item which has been developed is the selenium rectifier for underground mining applications. This rectifier can be placed at the point of use of d-c power for shuttle cars and other d-c mining equipment and by such an installation permit power distribution by high-voltage alternating current with relatively low power loss and with good voltage regulation. The selenium rectifier also has become a potential competitor for conversion of alternating current to direct current in mining substations.

Power

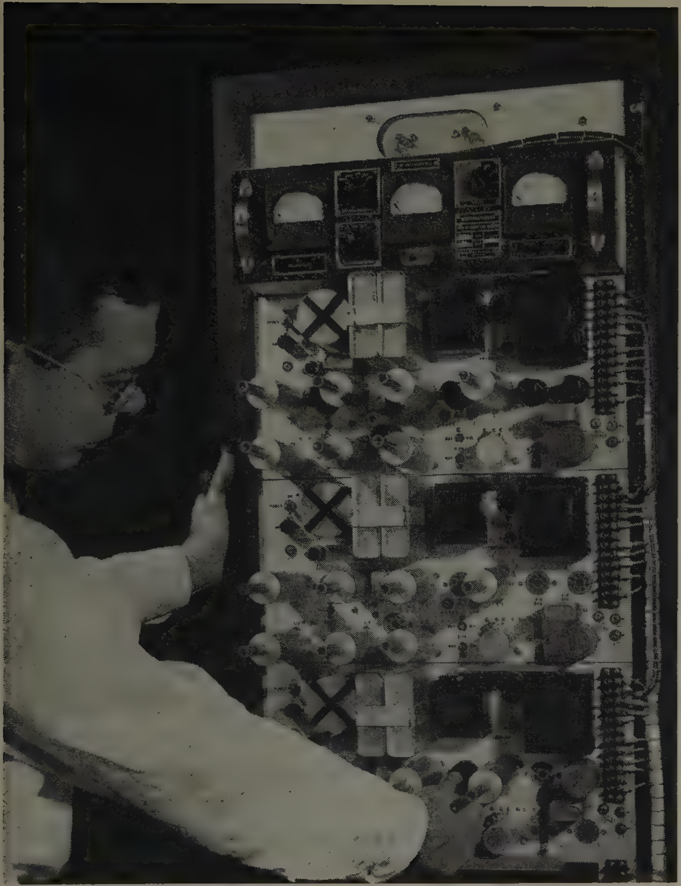
CARRIER CURRENT

Improvements in Phase-Comparison Relaying. Higher speed phase-comparison relaying has been obtained by a co-ordinated redesign of both the carrier-current and relay components. The high-speed operation is obtained under all fault conditions. The design affords complete independence for the telephone facility with the relaying taking precedence in the event of a fault. The carrier-current design uses long-life tubes and other modern components chosen for high reliability. The redesign produced increased selectivity and range in keeping with present-day carrier-current requirements.



Courtesy the Westinghouse Electric Corporation

The 960-megacycle equipment shown employs high-frequency triodes which normally give several thousand hours of full power output without attention



Courtesy Westinghouse Electric Corporation

Installations of several microwave (960 megacycles) communication equipments have been made on power-transmission systems for various combinations of communication, telemetering, relaying, and supervisory control. The equipment shown uses crystal filters in the frequency-shift circuit, making it less susceptible to interference

The new design of the carrier-current transmitter-receiver is also used for directional-comparison relaying.

New Applications for the Narrow-Band, Crystal-Controlled, Frequency-Shift Equipment. A new design of the crystal-type frequency-shift equipment provides the ultimate in reliability demanded for a transferred-trip relay channel. An installation of this type was placed in service recently after extensive field testing. Two parallel channels were used to eliminate the possibility of any single component failure causing a false operation.

In the past, it was necessary to use two crystal-type frequency-shift channels to send raise and lower load control impulses; however, the development of special circuits has made possible the transmission of raise or lower load-control impulses over a single-shift channel of this type.

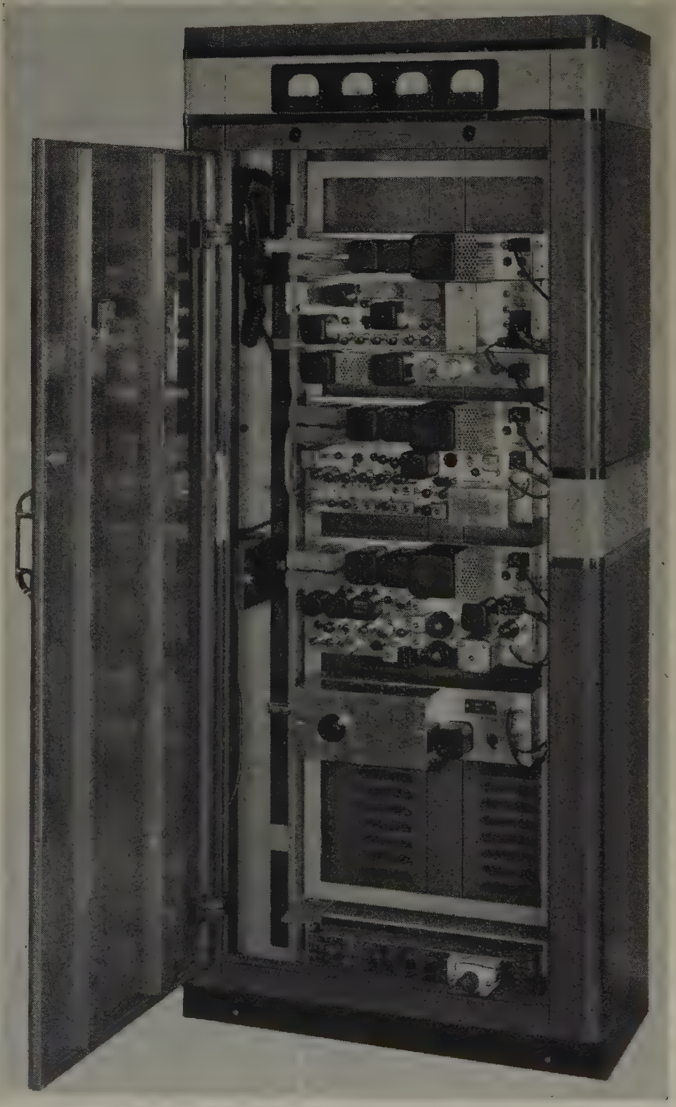
Another version of the crystal-type frequency-shift equipment provides greater range and freedom from noise for supervisory-control channels. This equipment operates on a keyed-carrier basis instead of frequency-shift and can be used for single-frequency party-line operation with as many as four outlying stations.

New Flexibility in Power-Line Carrier. Improvements aimed at increasing flexibility, extending application, and giving improved performance are being incorporated in power-line carrier equipment.

Frequency-shift equipment operated by alternating or direct current and suitable for low- and high-speed telemetering and control has been developed. Crystal-controlled, it permits minimum spacing between channels, thus permitting more functions to be carried out on a power system.

New tone equipment providing up to 18 tones in the voice-frequency spectrum replaces the previous 10-frequency tone equipment (*JY*). In addition, the new equipment can provide 16 frequencies above 3,500 cycles for application to microwave equipment (*FB*) and telephone lines. The units provide for protective relaying, supervisory control, transfer trip, and telemetering. Slow- and high-speed impulse rate, impulse duration, and frequency-type telemetering can be handled equally well.

New line tuners to provide more efficient and more flexible coupling of power-line carrier energy to power lines have been developed. Standardized components are featured which can be put together to provide single- and 2-frequency



Courtesy Motorola, Inc.

Precision selectivity carrier equipment in which duplex conversation on a single carrier frequency is accomplished

operation for both phase-to-ground and phase-to-phase connection to high line.

The Aperiodic Coupling Unit. A broad-band coupling unit has been developed for efficiently connecting a large number of carrier transmitters and receivers to a high-voltage power line through a single unit. This one unit takes the place of both the coupling capacitor and line tuning units of older type installations.

The unit has a nonresonant characteristic and it is essentially a high-pass filter section with the coupling capacitor acting as one of the series elements. Although the unit has only a single adjustment, it can be used to match effectively any line impedance above 200 ohms.

Selectivity Carrier Equipment. The need for an increased number of carrier circuits in modern power systems operation has led to the development of a complete line of narrow-band, frequency-modulated carrier equipment suitable for close-channel operation. All elements of the system, including transmitters, receivers, and control units, were complete new designs in order to achieve this performance.

The selectivity of the receiver is permanently established in a sealed filter; therefore, retuning at periodic intervals is not required. Placing this selectivity-establishing filter at the input of the receiver completely eliminates the problem of intermodulation and desensitization.

Modulation control limits side bands to those needed for intelligible communications and prevents interference with adjacent channels. The audio portions of the system have been designed to permit full channel utilization. Supervisory control, telemetering, and voice transmissions may be sent simultaneously on a single channel without mutual interference.

POWER GENERATION

Prime Movers. 1951 stands as a landmark in central-station prime mover history because three exclusively gas-turbine stations began operating for the first time. They are Graham Station of the Bangor Hydro-Electric Company, Rutland Station of the Central Vermont Public Service Corporation, and the Elk City Station of the Public Service Company of Oklahoma. All these plants have essentially the same type of high-efficiency gas-turbine unit, nominally rated at 5,000 kw by the manufacturer. Some of these units differ in detail.

All these gas-turbine stations will ultimately house two or more units. During 1951, the Public Service Company of Oklahoma announced letting a contract for a 15,000-kw high-efficiency gas-turbine unit for delivery in 1954. This is the largest unit yet announced in the United States but there is a 27,000-kw gas turbine now running in Switzerland.

The 3,500-kw gas turbine at Belle Isle Station, Oklahoma Gas and Electric Company, has been in practically continuous service since July 1949. This unit runs in parallel with the station feedwater system. The gas-turbine exhaust supplies some of the water heating need, thus cutting back on turbine bleed steam and raising steam turbine capacity. Operation has been entirely successful from efficiency, availability, and maintenance standpoints.

Continuing surveys made by the Edison Electric Institute show that if manpower and materials are available as needed, the capability of United States power systems will rise by almost 7,000,000 kw during 1951, by over 9,500,000 kw in 1952, and over 10,000,000 kw in 1953. This will set an all-time record of expansion in power generation history.

The average size of units that will be installed shows the effect of installing larger sized units. Maximum unit capacity will be 200,000 kw. The average size runs about 68,000 kw. More and more units are using temperatures of 1,000 degrees Fahrenheit. The highest will be 1,100 degrees Fahrenheit. Over 100 new units will use the reheat cycle. This cycle originally was designed to allow the use of higher pressures with limited steam temperatures at throttle to attain better thermal efficiency. At the present range of pressures and temperatures, up to 2,400 pounds per square inch gauge and 1,100 degrees Fahrenheit, reheat offers marked improvement in performance, even more than with limited throttle temperatures. There are about 80 reheat units now in operation.

Hydroelectric Generation. Outstanding and novel new developments on the Pacific coast include the McNary Plant with 14 70,000-kw units and the Chief Joseph Plant with 27 60,000-kw units, both on the Columbia River in the north and the three 37,500-kw fully automatic outdoor plants on the Owens River in the south.

Automatic tie-line load control over long distances reached a high state of development during the year and made possible greater conservation of available power. Subnormal and off-season precipitation on the Pacific Coast has seriously interfered with hydroelectric plant operations and led to unprecedented expansion of steam-electric generating facilities.

The most outstanding development in the hydroelectric field was the initiation of construction on a hydroelectric power plant in Canada which will have an ultimate firm capacity of 1,200,000 kw in 16 multiple-nozzle vertical impulse water wheel generating units. These units will operate at a head of approximately 2,600 feet. Generating equipment and transformers will be installed in an underground powerhouse with output fed to an outdoor switching station through 300-kv power cables.

Steam-Electric Generation. More than 1,000,000 kw of new steam generation was added during the year on the Pacific Coast and there has been a definite trend toward unit design, higher pressures, and temperatures and reheat. Improvements in equipment design and plant layouts have made possible the elimination of house units and steam-driven auxiliaries in the newer plants. There is a definite trend toward the use of higher atomizing pressures on oil burners to improve combustion, elimination of spare auxiliaries to simplify piping layouts, and the use of ion exchangers instead of evaporators because of economy. Water lancing of boiler heating surfaces has made it possible to use lower grades of fuel oil and yet operate the boilers at full capacity for a year between outages.

ROTATING MACHINERY

THE OUTSTANDING developments in the field of synchronous machinery are improvements in the design of large

Courtesy Reliance Electric and Engineering Company

An installation of a specially designed 520-horsepower force-ventilated d-c motor which is used to drive a triple-acting press

hydrogen-cooled steam-turbine-driven generators resulting in substantial savings in the amount of material and space required for a given rating. New methods of cooling the rotors use high-velocity gas in contact with the metal of the conductors. One 60,000-kw unit using this method of cooling is in service, and a 175,000-kw and a 200,000-kw unit are on order. Oriented electrical sheet steel is being used for the stator laminations in a number of generators to reduce the outside diameter of the stator.

In the field of induction machinery there has been a notable increase in the use of outdoor-type splashproof motors to reduce building costs. The size and weight of totally enclosed fan-cooled high-slip motors have been reduced by extending the rotor bars through the enclosure to more easily dissipate the rotor losses. Hollow tubes located between the coil ends of two 25,000-horsepower 860-rpm wound-rotor motors have improved the cooling and permitted them to operate at appreciable overloads.

A new 520-horsepower force-ventilated d-c motor was designed and built for use on large triple-acting presses used for forming automobile tops. This motor has excellent commutation over a wide range of speed, voltage, and current, with very high rates of change of current.

SWITCHGEAR

Circuit Breakers. During 1951 interesting tests which may influence future developments have been made on high-voltage lines to determine the action of various types of circuit breakers under such conditions as out-of-phase switching and switching of charging currents.

One manufacturer reports: "Further extension in interrupting capacity of oil circuit breakers for transmission voltages, 10,000,000-kva 161-kv circuit breakers having been built and shipped, and the same rating at 138 kv ordered by two large operating companies. Development of the 15,000,000-kva step at 230 kv has been requested. Developments in fast reclosing have included multiple reclosing as many as three times with intervals of 20-30-30 cycles, using a pneumatic mechanism on the 161-kv circuit breakers just mentioned."

Another reports that: "69-kv 3,500-megavolt-ampere air-blast circuit breakers in isolated phase metal-enclosed structures were produced for a completely metal-enclosed outdoor substation of the Consolidated Edison Company in New York." Further, "A new long life solenoid-operated air-blast circuit breaker rated 34.5 kv was developed for arc-furnace control."

Metal-Clad Switchgear. One manufacturer reports that a completely new design of metal-clad indoor and outdoor switchgear was introduced, embodying these significant improvements:

1. A high degree of component standardization permitting the manufacture of pre-engineered standardized functional units on a catalogue basis.
2. A new magne-blast circuit breaker with greatly extended interchangeability of parts among different ratings. As an example, identical operating mechanisms embodying an integral electromechanical control relay are used on all ratings.
3. A faster and more convenient elevating mechanism with positive-acting mechanical interlocks against raising or lowering a closed circuit breaker or operating a partially raised circuit breaker.
4. Liberal use of flame retardant insulating material in both the circuit breaker and stationary structure to minimize damage from accidental arcing.
5. A rigid welded framework specifically designed to withstand the stresses of shipment and installation.
6. Interchangeable cable entrance facilities to permit entry of cables from above or below at the user's option.

The development of a 23-kv 1,500-ampere interrupting capacity automatic reclosure for service on 14.4/24.9-kv rural distribution lines also was reported.

TRANSMISSION AND DISTRIBUTION

The first high-voltage series capacitor at 230 kv in the United States was placed in service in 1951 at Chehalis, Oreg., by the Bonneville Power Administration. A 220-kv series capacitor had been in operation in 1950 at Alfta, Sweden. The Chehalis capacitor incorporates an improved protective system which provides for quick reinsertion of the capacitor, following a system disturbance or short circuit. This increases the effectiveness and reduces the cost of the capacitor installation when used to increase the stability of the system. Series capacitors have been studied for many years as a possible means for decreasing the cost of long-distance power transmission lines. This installation is another noteworthy step in the progress of high-voltage transmission.

Other applications of series capacitors have been reported within the past year for load-balancing between paralleled circuits and for reducing light flicker. Shunt capacitors also were given attention, particularly as to their application for reducing system costs and for providing system voltage control.

High-voltage transmission was further advanced by studies made of corona and radio interference, lightning protection, and the mechanical vibration of conductors.

In the field of distribution, methods of protecting long low-voltage feeders were studied—in particular, use of repeating fuses and automatic reclosers. Studies were continued to determine the system recovery voltage characteristics as necessary information for the proper application of protective equipment on suburban and rural feeders.

Progress in improving the economy loading of large interconnected systems by methods which include the effect of incremental transmission line losses, as well as the incremental fuel costs, were reported and show possibilities for substantial savings.

Improved methods of calculating performance of transmission systems and the development of analogue circuits, to more accurately represent complex phenomena on a-c network analyzers, also were developed during the past year.

These advances during the past year are significant steps toward improved reliability and reduced costs, both in investment and operation of transmission and distribution systems. Continued rapid progress in this field can be expected.

Science and Electronics

COMPUTING DEVICES

PROGRESS IN THE development of computing devices continued at a rapid rate during 1951, with some 90 organizations now making or developing such equipment.

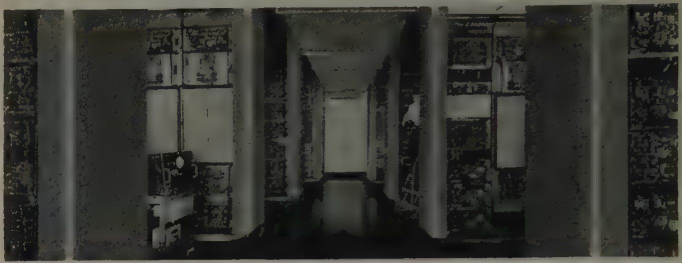
Large-Scale Digital Computers. A number of these machines went into service. Among them are the Whirlwind I, the Univac, model *1101*, and the Laboratory Computer. In England, a concern completed and put into operation an electronic calculator for the University of Manchester.

Courtesy Northrop Aircraft, Inc.

The MADDIDA computer is a type of electronic digital differential analyzer which serves as a desk-type calculator. It can solve both linear and nonlinear differential equations of any order or degree and is adaptable to control and simulation work

Magnetic tapes and drums are popular types of intermediate-speed storage. High-speed devices in service include mercury delay lines, special electrostatic storage tubes, and modified standard cathode-ray tubes. Punched cards continue as useful tools for recording and arranging data.

Production Model Electronic Digital Computers. One manufacturer has passed the 900 mark during the year on its model *604* electronic calculator and started shipping model II card-programmed electronic calculators. Another company announced its type *409* electronic calculator, with punched card input and output.



Courtesy Massachusetts Institute of Technology

Main aisle of the Whirlwind I Computer has racks of electronic equipment extending toward the sides. Over 4,000 vacuum tubes are contained and some 18 times this number of electronic components. Its speed of 20,000 single-address operations per second makes it suitable for use in real-time control systems

Analogue Computers. The progress in analogue computers was significant, with a rapid expansion in the number of Reacs built and special-purpose analogue computers being built by a number of firms. Four additional large-scale, general-purpose electric analogue computers of the same design as the machine at the California Institute of Technology are under construction for various aircraft companies. The Magnetic Drum Digital Differential Analyzer (Maddida) combines both analogue and digital features.

Applications of Computers. Many of the large computers are at work on classified projects. The Naval Proving Ground reported the completion of extensive fire control computations on its Mark III calculator. From computations performed on the SSEC, the United States Naval Observatory is publishing a volume of more accurate tables on the positions of the great planets.

Aircraft structure design, ballistics, heat transfer, nuclear physics, and data reduction problems are among the major subjects of machine computation. The smaller electronic digital calculators are important units in many business machine installations.

ELECTRICAL TECHNIQUES IN MEDICINE AND BIOLOGY

DUE TO THE progress in research in pure physics, with a resulting improvement in techniques and instruments, the use of electronic instrumentation in medicine has advanced. An example is the employment of cobalt 60 as an X-ray source instead of radium for the treatment of deep-

Courtesy General Electric Company

The 16-ton synchrotron constructed for the University of California, which will have auxiliary machinery to move the magnet to adjust precisely the X-ray beam between 20,000,000 and 70,000,000 volts

seated cancer. The Hevimet container, permitting complete control, insures protection against radiation at all times.

In the realm of research for treating deep-seated cancer, a synchrotron that produces an X-ray beam of 70,000,000 volts is being installed at the University of California School of Medicine. This atom-smasher will develop the most powerful X-ray beam ever generated specifically for the treatment of cancer. The synchrotron will not be used in the treatment of patients for some time to come but the early work will be devoted to determining the effect of the ultrahigh-energy X rays on animals.

Encouraging advances during the year have been made in the intensification of X-ray images using several different methods. By means of a new television camera tube of increased efficiency microscope images now can be shown to large groups on television screens. Also in the operating theater the color television camera provides medical students with close-ups of operations without interfering with the surgeon's work.

A further development has followed the observation that the electrical output of the brain decreased as anesthesia deepened. The result is an electromechanical servo system that automatically delivers the anesthesia to a patient at a rate so that the desired depths of anesthesia can be maintained for long periods.

ELECTRONIC POWER CONVERTERS

Excitrons. Two developments are reported in excitron rectifiers, a new 400-ampere sealed-tube and a new heavy-duty pumped-tank excitron. The new sealed tube is designed for 250-volt industrial, 275-volt mining, and 600-volt railway service. Six tubes are mounted in a steel enclosure together with the necessary excitation, phase control, and cooling equipment.

A 600-volt outdoor unit is being designed for railway service. The new heavy-duty pumped-tank is mounted in groups of 6 or 12 on a frame, together with the evacuating and cooling equipment, for ratings of 3,000 or 6,000 amperes. A vitreous-enamel bushing is used for the anode lead-in. Teflon gaskets are used at all demountable joints and vacuum welding reduced to a minimum. The ignition-excitation system has been greatly simplified.

Mechanical Rectifiers. The past year has seen continuous improvement in the mechanical rectifier and a high degree of standardization. An important feature of the latest unit is direct air cooling, eliminating the use of water, water pump, and insulating tubes, all sources of annoying maintenance problems. The commutating reactors have been placed inside the main transformer tank, providing almost complete packaging, reducing the space requirements, and simplifying installation. The transformer tap-changer handle is brought into the rectifier cubicle and interlocked to prevent operation under load.

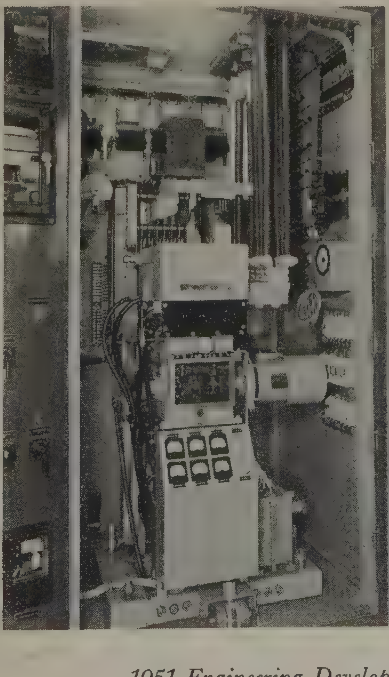
INSTRUMENTS AND MEASUREMENTS

New developments in the instrument field have been numerous and quite diversified, covering the entire range of the frequency spectrum.

One manufacturer has announced new single-phase and polyphase self-contained combination watt-hour and thermal-watt demand meters for higher currents. Another also announced two new types of combination polyphase 2-element thermal demand watt-hour meters.

A compact new direct-reading exposure meter has been designed. It produces an approximate logarithmic re-

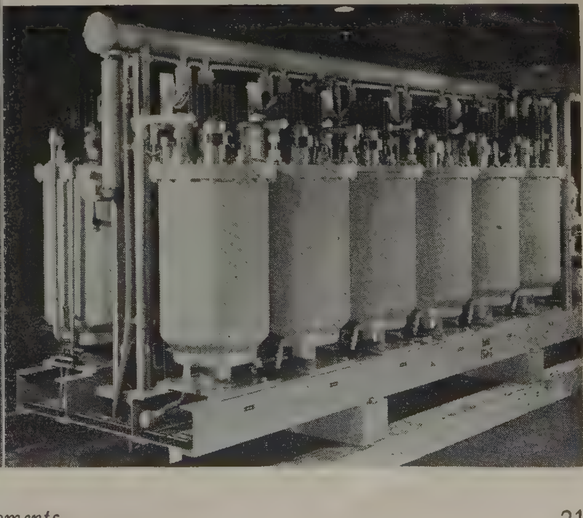
Courtesy I.T.E. Circuit Breaker Company



This 5,000-ampere mechanical rectifier (at the left) was installed at the Buffalo Electro Chemical Company, Inc.

Below is shown the 12-tube rectifier assembly for heavy-duty service

Courtesy Allis-Chalmers Manufacturing Company



sponse characteristic which allows the dial to be calibrated directly in f-stops.

A new ratio-type instrument which can be used as a controller was developed for use with resistance temperature detectors in industrial process instrumentation, especially in the −50 degrees centigrade to +150 degrees centigrade ranges.

Two new electronic null-type recorders have been announced. One, a 2-pen instrument, records two functions as continuous curves simultaneously against time on a wide strip chart. The second recorder permits highly precise automatic recording of temperatures over a range of −200 degrees to +500 degrees centigrade and is, in effect, a Mueller Bridge that automatically records its own measurements in increments of 0.01 degree centigrade.

The Inductronic D-C Amplifier, a precision amplifier for d-c measurement and control particularly suited to industrial processes requiring continuity of service with a high degree of stability and accuracy, has been brought out.

Principal advances in the mobile field of telemetering have been in crystal-controlled radio links, improved airborne component subassemblies, and in receiving, recording, and analyzing equipment. The need for closer spacing of radio-frequency transmitters has sparked development of crystal-controlled frequency-modulated radio transmitters. A revolutionary method for eliminating any spurious movement of a magnetic tape during its passage past a recording or reproducing head has been perfected.

New equipment has been designed to provide automatically calibrated function versus time graphs from magnetic galvanometer records. They employ mechanical-optical flying spot scanners. One converts the photocell output into digital pulses for storage and later translation; while the other uses analogue techniques.

In the field of stationary telemetering, extensive additions to a number of power generating and distribution systems have raised many problems of control. A new high-speed telemetering system has been described which uses frequency as a translating means. Equipment has been built to operate on two bands of 20–25 cycles per second and 80–100 cycles per second.

The change to radio links to replace wire links has been continued in point-to-point applications involving great distances or relatively unaccessible locations. Many of these links employ microwave equipment, while others operate in the 200-megacycle band.

The performance of the industrial type of cathode-ray tubes was improved in deflection sensitivity and optical quality of face and screen performance. A method of minimizing deflection defocusing by use of an auxiliary focus electrode was described. Multiband cathode-ray tubes were developed capable of writing speeds in the ultrahigh-frequency range of more than 3,000 inches per microsecond. The design of instruments using distributed amplifiers was improved and their frequency ranges and gain extended. Sweep circuits suitable for use at frequencies of 200 megacycles or more were developed.

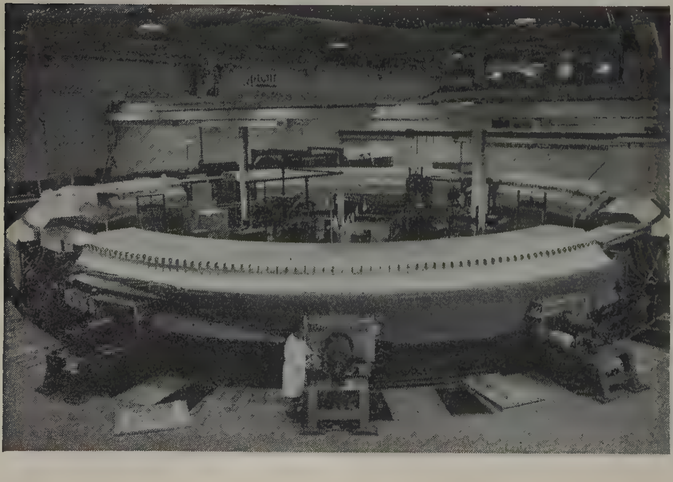
A device to plot any set of data on a cathode-ray tube together with linear or nonlinear co-ordinates scales was described. An oscillograph for plotting of transients of more than 30 seconds in duration was developed.

Iconoscopes and image tubes were used as high-speed shutters for photographic purposes. Oscillographs were used to measure dielectric polarization under transient conditions. A new water-cooled d-c carbon arc has been developed in the physics department of The Johns Hopkins University as a source of radiant power for infrared microspectroscopy. One laboratory announced a newly designed helical mercury lamp for Raman spectroscopy.

The Applied Research Production Control Quantometer has been redesigned to improve reliability of performance over longer operating periods.

The developments in the field of high-frequency measurements in 1951 were highlighted by the continued interest and improvement in atomic frequency and time standards, the use of sweep frequency techniques in the measurement of standing-wave-ratio and impedance, and the use of photographic techniques in measuring microwave field patterns.

Brookhaven Cosmotron Under Construction at Upton, New York



The Brookhaven National Laboratory's cosmotron is shown in its latest phase of construction. The ring-shaped magnet has an inside diameter of over 60 feet and weighs 2,200 tons. To produce the required magnetic field in the gap, the magnet is given 1-second pulses of power from a generator which delivers a peak of 40,000,000 watts. The vacuum pumps, such as those shown in the foreground, will evacuate a vacuum chamber so that the accelerated atomic particles will not suffer collisions with gas molecules during their 3,000,000 trips around the magnet. The vacuum chamber, which is inserted into the magnet gap, is nearing completion as is the high-power amplifier which will speed up the particles to their final energy of 2,000,000 electron volts. After having attained full energy, the accelerated protons will be permitted to strike targets of carbon or liquid hydrogen. It is expected the results of these collisions will lead to a better understanding of forces within the nucleus

The Professional Interests of Engineers

I. M. STEIN
FELLOW AIEE

By calling attention to the many aspects of the problem of recognition and unification of the engineering profession, the author hopes to indicate the scope of the analysis that is needed before attempting to solve the problem.

FOR MANY YEARS the relation of our Institute to the professional interests of its members has been under discussion. At the 1937 Summer General Meeting in Milwaukee, Wis., we had three excellent addresses on this subject by Dr. Vannevar Bush, Dr. Ralph E. Flanders, and Past President A. M. MacCutcheon. More recently the discussion has centered around expanding the nontechnical activities of our Institute, recognition and unification of the profession, and a unity organization. These discussions have been helpful, but the situation remains confused.

The confusion may be the result of failure to make a sufficiently comprehensive and thorough analysis of the problem before attempting to solve it. Much of the recent discussion seems to be focussed on proposals, by individuals or groups, dealing with limited phases of the general problem, and on the opposition by other individuals or groups to these specific proposals.

Should we not have a thorough analysis of the general problem followed by agreement on a set of principles to be used as a guide in taking whatever additional steps may be desirable? Is it not premature to ask the members to vote yes or no on specific forms of organization in advance of making such an analysis and establishing such a set of principles?

It is not the purpose of this article to present an analysis or the guiding principles. The purpose is rather to call attention to some of the many aspects of the problem in the hope that this may indicate the scope of the analysis needed.

WHAT ARE THE PROFESSIONAL INTERESTS OF ENGINEERS?

AT THE OUTSET we need a clear idea of what we mean by professional interests. Many discussions on this subject confuse the professional interests of engineers with the ordinary attributes of good citizenship. Like nearly every one else, an engineer must earn a living for himself and his family, and he should strive to be a good citizen. These are not his professional interests. Superimposed on these interests are the plus qualifications of the professional man. It is these plus qualifications to which we must direct our thinking in talking about the professional interests of the engineer. In general terms, they are the same as the qualifications of any professional man, as follows:

1. The professional man should not put his own interests above the public interest.
2. He should be sound in his work, reliable in his statements, and should adhere to the extra ethics as established for his profession.
3. He should be willing to donate to the public a reasonable amount of his time in his professional capacity, and should take the initiative in finding opportunities to do this.
4. He should have such a keen interest in, and respect for, the work of his profession as to give him great personal satisfaction in his own work.
5. He should seek to advance the profession which trained him by contributing to its literature, by contributing some of his time to training young men entering the profession, and in other ways.
6. He should have a creative spirit which impels him to strive to make our world a better place as the result of his having lived in it.

Although this list is a challenging one, it does not include the obligation to take an active part in community and civic affairs except in a professional capacity. Of course, professional people should take part in nonprofessional civic activities, but they should do so as good citizens rather than because of professional interests. Such nonprofessional activities are the concern of the individual as a citizen, and are not the concern of his professional organization, unless it should be necessary for the organization to remind its members of the essentials of good citizenship.

The more specific professional interests of engineers may be stated in a somewhat different form as follows: public protection; education of the public on engineering matters; government activities related to engineering; advancement of the engineering profession; co-ordination of science and technology; economic status of the engineer; and organization of the engineering profession.

Public Protection is primarily a matter of the establishment and recognition of standards or codes. Such standards or codes cover materials, procedures, and men. Their establishment and recognition are responsibilities of the professional engineering organizations, but involve co-operation with, and concomitant action by, other organizations and sometimes by legislative bodies. Safety codes, codes of ethics, test codes, and licensure of engineers are examples. Codification based on sound technology is needed to avoid hazards, and codification based on progressive technology is needed to avoid economic waste and waste of human values.

Education of the Public on Engineering Matters is a much neglected professional interest of engineers. It is a joint responsibility of the organized profession and of the leading individuals in it. Outstanding engineering accomplish-

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. M. Stein is Executive Vice-President of the Leeds and Northrup Company, Philaelphia, Pa.

ments should be interpreted to the public in terms of the public interest. Also, the long-term accomplishment should be reviewed and interpreted. The preparation and presentation of such papers are the responsibilities of broad-gauge, leading engineers. The presidents and past presidents of our major engineering societies ought to be able to prepare and present such papers, but the organized profession should see to it that the papers are presented and should arrange proper forums for their presentation.

The social and economic impact of technological progress should be a part of this program. Scientists and engineers may take the position that they should not be held responsible for adverse effects of their contributions. It is unnecessary to argue that point. The public will be told of these adverse effects, and if the telling is left to nonengineering groups the public cannot be blamed if it receives a less than accurate impression. Scientists, engineers, and their professional organizations owe it to the public and to themselves to have the effects of technological progress presented as fully and accurately as possible. A masterpiece presenting a long-range review of engineering contributions is the late Bancroft Gherardi's 1928 AIEE presidential address entitled "Civilization and the Engineer."[1]

Consideration of proper forums for such addresses involves the aspect of effective publicity at low cost. The annual meetings of the American Association for the Advancement of Science (AAAS) receive a great deal of nation-wide, and even world-wide, publicity. The Engineering Section of the AAAS should welcome addresses, such as Gherardi's, on its annual program. This forum, with its attendant publicity, is open to the engineering profession without cost. Perhaps there should be an annual engineering forum under the auspices of Engineers Joint Council with radio and television features. This would not necessarily involve any substantial cost to the engineering profession. Whatever might be the best channel and sponsorship, the presentation would have to be of a clearly superior type. A superficial program of self-praise probably would be a negative asset. The real measure of success of such a program can never be its cost or the number of lines of newspaper publicity it receives. It can be judged only by its real educational effect on the public.

Government Activities Related to Engineering are many and varied. Yet they can be classified and it should be possible to formulate procedures for dealing with each of them The following classification may be helpful.

1. Legislation affecting the status of engineers. The Wagner Act and the Taft-Hartley Act are examples. The impact of military service legislation on the supply and utilization of engineers is another. Such legislation pertains to professional status rather than to technology, and in such matters it would seem desirable for the several engineering societies to work with, and through, an organization concerned primarily with professional status.

2. Legislation, or legal procedures, in which technology is inherent; for example, patent matters. In the specific case of legislation pertaining to patent matters, it would seem highly desirable to work in collaboration with the Patent Law Associations whose members, incidentally, are mostly engineers. The remainder usually would be found to have had a formal training in science.

3. Legislation pertaining to projects involving engineering. Legislation of this type involves professional interests of the individual engineer and of the organizations representing the profession. In both cases, however, these are limited. The organization has the professional interest of having the engineering features discussed fully and adequately and should co-operate in obtaining competent engineers to submit expert testimony. Such testimony should not go beyond the engineering phases of the matter, which, in many cases, may be only a part, even a minor part, o the project as a whole.

In giving such testimony, particularly in instances where the engineering features may be a minor part of the whole project, the engineer must distinguish clearly between his professional interests and his interests as a citizen, because he may hold opposite views regarding the soundness of the engineering phases and the soundness of the project as a whole.

4. Government Contracts. These contracts, whether of a construction or development nature, are of interest to professional engineering societies, particularly to encourage contract terms pertaining to the employment of professional personnel that are not inimical to the professional status of such personnel, and to encourage the use of engineering standards established or sponsored by engineering societies.

Advancement of the Engineering Profession is a paramount professional interest. The engineers' professional interests in this matter are basically the same as the interests of other professional people in their professions, and are indicated in my earlier discussion of the qualifications of a professional man. I should like to emphasize the professional man's obligation to contribute to the literature of his profession, and the obligation of his professional organization to build and preserve an adequate literature.

Co-ordination of Science and Technology, although not neglected entirely, has had far too little attention. It cuts across practically all other professional interests. If World War II did nothing else, it demonstrated clearly the direct dependence of our national defense on engineering and the related sciences, as well as science generally. Moreover, it gave added emphasis to the overlapping of science and technology and their interdependence. To assure the greatest effectiveness of our scientific and engineering resources there is great need for rationalization without restriction of action in the specific fields. In matters involving government relations, scientists and technologists, other than engineers, may be as much interested as are engineers. The views of such groups may differ from those of engineers even on technical matters. Hence, there should be co-operation with the organizations representing these other professions. Without such co-operation awkward situations may arise in connection with hearings on legislation. It would be unfortunate to have the engineers aligned on one side of a question with the physicists and chemists on the other, because offsetting one group against the other would tend to nullify the scientific and technologic evidence as a whole.

Economic Status is, of course, an important professional interest, if only because a satisfactory economic status is necessary to attract an adequate number of competent men. The profession cannot meet its responsibilities if a sufficient number of competent men are not so attracted. Unfortunately, there has been some none too careful thinking and talking by engineers about this particular professional interest. The engineering societies, through Engineers Joint Council, made a rather comprehensive survey of the economic status of engineers. This, of course, must be repeated from time to time. Although similar data are not as yet available for the medical and legal professions, there is a tendency on the part of some engineers to make unsound comparisons with those professions. It is a human failing to compare one's economic status with outstanding leaders in other walks of life, but engineers, above all others, should not attempt to draw conclusions in the absence of the facts. A discussion of the whole subject of the economic status of engineers is too lengthy to be included in the present article, but the hope may be expressed that any concerted effort made by the engineering profession to improve the economic status of engineers would be made on a high professional plane, and on the same sound basis that engineers insist upon in their technical activities.

Organization of the Engineering Profession has been placed last in the list of professional interests, not because of any lesser importance, but because it can be discussed more intelligently after having reviewed some of the professional interests which the organized profession must serve. The real professional interests of engineers would appear to fall generally into two classifications: those having to do with matters of technology, and those having to do with what we may call professional status. The dividing line, however, is not clean cut, nor need it be. For instance, proper guidance of young men entering the profession is a matter of professional status, but is associated so closely with the technical activities of both the younger and the older engineer that it probably should be classified with technical activities. On the other hand, expert testimony given by an individual engineer before a congressional committee is a technical matter, but the individual's willingness to render such service to his government without charge is a matter of professional status.

Nevertheless, there would seem to be sound practical reasons for the classification suggested. First, matters of technology differ widely in the various branches of engineering, whereas matters of professional status are the same, or nearly the same, in all branches of engineering. Second, matters of professional status are much involved with legislation at the national, state, and local levels and, for the most part, legislation cannot be different for different branches of engineering. Also, the most effective representation of the profession on legislative matters could be expected through one organization rather than several, and through an organization having divisions that follow the usual political subdivisions, each with power to act within its subdivision rather than through an organization with divisions on some other basis and without power to act.

LESSONS FROM EXPERIENCE AND HISTORY

In considering the organization of the profession and also the recognition of the profession, which is one of the things proper organization is expected to establish, we have much to learn from experience and history.

The experience with American Engineering Council (AEC), which was organized shortly after World War I and which went out of existence about a dozen years ago, is one from which we should learn. Many able and public-spirited engineers gave unselfishly of their time and effort to AEC activities, and some good work was done for which all credit is due. The important point is that AEC was never so organized as to enable it to become the type of organization that many engineers hoped that it would. AEC was not organized to obtain and make use of the views of the engineers comprising the profession. In fact, it was not organized in a way to obtain the views of even the small number of engineers comprising the boards of managers of the major engineering societies which gave AEC its principal financial support. Primarily, for these reasons American Engineering Council has ceased to exist.

In sharp contrast with AEC we have the National Society of Professional Engineers, which has been in existence now for more than the full life span of AEC and which gives every indication of survival and expansion. Although some changes in this organization would appear essential to make it generally acceptable as the representative of the whole engineering profession in matters of professional status, some of its features which probably are responsible for its success to date are worth noting:

1. Its financial support comes directly from its individual dues-paying members.
2. It is organized on a local, state, and national basis so as to be able to deal effectively with legislation at these levels.
3. It keeps its individual members currently informed of legislation affecting the profession and of the organization's position with regard to such legislation, so that individual members have an opportunity to submit promptly their own reactions.
4. Its position on legislative matters appeals generally to its individual members. At state levels it has supported legislation restricting the practice of professional engineering to qualified persons, while at the national level it has opposed legislation which would restrict freedom of choice of its individual members in matters affecting professional status and has supported legislation which would preserve or gain such freedom of choice.

Based on these two specific experiences and on more general experience, it is probably safe to say that the success of any institution depends in large measure on its being organized properly to meet stated objectives and then confining activities to those objectives.

Professional societies organized to promote certain professional interests of engineers should not speak for the profession on matters beyond these interests. To do so almost inevitably would weaken their position in fields where they should be able to speak with authority. Professional technical societies should limit their statements to matters of technology, including education and training in technology. The constitutional requirements for membership in such organizations involve just two things. A member must be a person of good character, and second, must be competent technically. Individuals of unquestionable character and technical competence may hold widely divergent views on nontechnical matters, and the officers of these technical societies are not so chosen as to make them proper representatives on such matters. Even professional engineering societies organized to deal with nontechnical professional interests cannot, in general, provide a single voice for the individuals in the engineering profession, because in many cases no majority opinion, much less a unanimous one, will exist.

Those who would pattern the organization of the engineering profession after the organization of the medical profession present an argument which is of doubtful validity for at least the following reason: the engineering profession is made up predominantly of employed persons having four years of college education, and working in widely different fields, whereas the profession of medicine is made up predominantly of persons operating as individuals, having seven years of college education plus a rigorously controlled period of internship, and working in fields all related to the human body.

On the other hand, in the matter of recognition of the profession much can be learned from the history of the medical profession. The recognition of the medical profession probably stems as much from two other factors as it does from the outstanding advances in the sciences of medicine and surgery. These are adequate publicity and the characteristic display of the attributes of professional men as outlined earlier in this article. Although the language of medical men, as used within their profession, is practically impossible for the lay public to understand, the news releases to the newspapers and nontechnical press are in language the public thinks it can understand and, perhaps of even more importance, the story is focussed on points of individual personal welfare. Contributions, financial and of other types, to the support of the profession by its members have been characteristic of the medical profession for a long time.

In the early part of the century Theodore Roosevelt said, in effect, "every man owes something to the profession of which he is a part." That was not a new idea to the medical profession. About 2,500 years ago Hippocrates, who lived in the 4th and 5th centuries B.C., established the famous Physician's Oath or Hippocratic Oath, which is repeated down to this day by men about to enter the medical profession. Hippocrates was seeking recognition—"reputation among all men for my life and my art." There was no American Medical Association in those days. The teachers alone were the cornerstone of the profession, whereas today that position is shared by the teachers, the educational institutions, and the professional organizations. Every man seeking professional recognition should ponder carefully the words of this oath.

"I swear by Appollo Physician, by Asclepius, by Health, by Panacea, and by all the gods and goddesses, making them my witness, that I will carry out, according to my ability and judgment, this oath and this indenture. To hold my teacher in this art equal to my own parents; to make him partner in my livelihood; when he is in need of money to share mine with him; to consider his family as my own brothers, and to teach them this art, if they want to learn it, without fee or indenture. I will use treatment to help the sick according to my ability and judgment, but never with a view to injury or wrongdoing. I will keep pure and holy both my life and my art. . . . Now if I carry out this oath, and break it not, may I gain forever reputation among all men for my life and my art; but if I transgress it and forswear myself, may the opposite befall me."

RATIONALIZATION

In seeking to advance the professional interests of engineers, we have had much discussion on the unification of the profession and a unity organization. In Dr. Bush's 1937 address[2] he referred to integration. A better idea of our needs would seem to be expressed by the word rationalization because that term gives just as much emphasis to desirable segregation, or separation, as it does to the reverse—and that is quite proper. Moreover, rationalization is broader in the sense that it can and should be applied to the whole field of technology including, in addition to engineering, all fields of science related to engineering.

The need for rationalization among the many scientific and engineering societies extends beyond their basic technical activities and matters of professional status to include common operational matters of which publications may be cited as one very important example. Economy in providing adequate publications is a matter of great concern not only to all of these societies but also to advertisers and those who purchase the publications or provide space for them in their libraries. Some progress has been made in this direction but much more remains to be done.

Within the engineering profession there is great need for rationalization regarding organizations concerned primarily with the several fields of technology, and an organization representing the whole profession and concerned with professional status. The types of organization needed for these two general fields of professional interest would appear to be basically different.

With proper rationalization within the engineering profession and between the engineering profession and the professional organizations representing the broad field of related sciences, we might look forward to a Joint Council on Technology and a National Society of Professional Technologists, both representative of the whole field of engineering and the related sciences. Eventually, there might arise in a proper location a temple of technology providing headquarters' facilities, library, meeting-room, and auxiliary facilities for all the professional societies representing engineering and the related sciences.

Before real progress in organization can be expected, it would seem necessary to make a comprehensive analysis of the professional interests to be served and to obtain agreement, among the various groups involved, on a set of principles and objectives to be met.

REFERENCES

1. Civilization and the Engineer, **Bancroft Gherardi.** AIEE *Transactions*, volume 47, October 1928, pages 1409–11.

2. The Engineer and His Relation to Government, **Vannevar Bush.** *Electrical Engineering*, volume 56, August 1937, page 933.

Adequacy and Standards of Engineering Education

S. C. HOLLISTER C. S. CROUSE L. F. GRANT M. D. HOOVEN
FELLOW AIEE

THE AIM OF THIS report is to present, at least in spirit, the impressions of the committee concerning the adequacy of present-day engineering education and observations relating to what it estimates to be the standards employed by the engineering schools. Any attempt to appraise the present position of engineering education is destined to cause a certain amount of misunderstanding, due largely to the attitude of the reader at the time, and the impression the words convey in the climate provided by that attitude. Specific statements are often too limiting when taken literally, and generalizations are often too vague. An endeavor has been made, however, to present for consideration the committee's views on the present situation with the hope that, though brief and at times oversimplified and specific, the main observations will be accepted in their intended perspective.

GROWTH OF ENGINEERING CURRICULA

ENGINEERING EDUCATION in America was not developed after a preconceived plan. It evolved in parallel with the needs of a growing country, a country engaged in the development of a vast industrialization. From the first it filled a practical need, and its design emanated largely from an evaluation of the professional requirements.

There were only a half-dozen schools of substantial merit by 1866. While the concept of engineering was the application of science to useful purposes, the educational program was heavily charged with the art of engineering practice. The better curricula had their roots in scientific studies. At that time, and for a generation to follow, a majority of practicing engineers were not engineering college graduates; they were men who through experience, observation, and study developed themselves to the point where they could cope with the technical problems of their time. Books began to appear and, with the development of laboratories for the teaching of principles (which, by the way, had been by 1870 in operation for 15 years in the Chemistry Department at the University of Michigan), gave strength to the program of the colleges in systematization of technical knowledge.

With the passage of the Morrill Act in 1862 the means and urge to found in each state a program in the mechanical arts for the aid of manufacturers were at hand. From 1870 to 1896 there was rapid expansion of the number of schools to 110 and the gradual formulation of the curriculum. By 1910 the forms of curricula in the older branches of the profession were pretty well standardized as to pattern. No elevating influences appeared to be at work on other than the newer curricula, such as chemical and metallurgical engineering, until World War I.

Between the two World Wars the engineering schools developed programs in electronics. Although these and the newer prewar programs were patterned after the "standard" form of curriculum, they nevertheless introduced new elements of strength in the increase of basic and applied science; and it was soon noticeable that they possessed more vitality and potential than the older programs. Yet most schools did little or nothing about these older curricula. Instead most colleges of engineering were preoccupied with the development of various offerings to cover students interested in the fringe areas: those who would be contiguous to, but not really a part of, engineering itself. While these programs served a useful need, their inclusion in one guise or other as engineering programs was a clear departure from the earlier concepts of professional training.

During the entire period from the earliest days to World War II, there was not an established position for the technical school offering a program that would be post-high school but with more emphasis on high-grade craftsmanship training than on professional education. Many of the earliest schools of this type gradually expanded to 4-year programs. A few, having a clear view of the need and great importance of such training, have held to their convictions and have developed strong programs with notable results.

CRITICAL EVALUATION OF FACTORS IN ENGINEERING COLLEGE DEVELOPMENT

AS THE HISTORY OF the growth of engineering colleges and their development is examined, certain features are especially evident. The very rapid expansion in both number and size of schools left little choice than to imitate the more successful. Not so obvious was an underlying situation that many of the new schools had only a dim concept of their objective in service to the engineering profession.

There was at work in the same setting the notion of spreading higher education for all, a factor that is restrictive of high standards. As the schools grew, the pressure for staff expansion led to recruiting by the simple process of keeping on recent graduates and then allowing them to do their graduate work, if any, while teaching. In this way, there was a subtle influence of continuity of curriculum with little urge for re-evaluation or vitality of

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Full text of a report prepared by the Engineers' Council for Professional Development Special Committee on Adequacy and Standards of Engineering Education.

S. C. Hollister, Chairman of this special committee, is Dean, College of Engineering, Cornell University, Ithaca, N. Y. **C. S. Crouse** is with the University of Kentucky, Lexington, Ky. **L. F. Grant** is with the Engineering Institute of Canada, Toronto, Ontario, Canada. **M. D. Hooven** is with the Public Service Electric and Gas Company, Newark, N. J.

concept of objectives. A standard pattern was achieved, not so much by deliberative process as by a sort of combination of gravitation and inertia.

Coupled with these influences was the circumstance of ever-pressing financial problems in young and growing schools, and the consequent limit on salary scales. Not a few administrators found themselves unable to pay salaries that would command talent already developed, and in some cases they could do little more than employ something less than the top of the currently graduating class—"temporarily." The deadening effect of obsolescence upon laboratory equipment, some of it hard-won after years of waiting and planning, had its part in gradual "standardization" through the lack of means to preserve a dynamic program.

Over the years, the number of practicing engineers without engineering college education was gradually diminishing. This was due in part to the availability of engineering schools, and to an increasing extent to the complicated nature of the engineering function. Between the two World Wars, with the introduction in many schools of programs with greatly reduced scientific and technical content, yet calling the output "engineers," there arose increasing confusion as to what constituted engineering and what characterized engineers. Accountants, for example, and graduates of business courses, and others, who had enterprise to pose as consultants on managerial matters, called themselves management or industrial engineers. Graduates of such courses could perform but elementary engineering functions. There can be no question that these courses of reduced technical content were an aid to certain persons; the serious doubt was whether they should have been considered engineering courses.

From the earliest days the program of engineering education was limited to four years, in parallel with the usual undergraduate college program. A very few schools added one or two years, with an additional degree. During the period of development and growth, the medical, legal, and architectural professions have extended their length of program to meet their particular objectives. It is significant that these developments had no effect upon the engineering professional program and that in consequence, with conspicuously few exceptions, the engineering curricula have remained four years in length, beginning immediately after high school.

Meantime, the fields of sciences, without exception, have been obliged to extend their programs through the addition of graduate work. Today no scientist is considered adequately trained without the doctor's degree. Whether graduate work is an appropriate program for the professional engineer is one of the questions dealt with by this committee.

Probably the most significant single characteristic of the engineering educational field is that it has no generally accepted professional objective as a goal for the educational program. There is general agreement respecting the form of the curriculum. It is difficult to detect differences in programs between schools simply by comparison of curricula. The major differences lie in the depth of instruction and in the objective of each institution in respect of the professional outlook to be achieved. There exists today a spectrum of objectives ranging from highly professional programs supported by strong science backgrounds to vocational programs in which only a moderate amount of science is included.

It is possible to divide the subjects included in any engineering curriculum into five groups, as follows:

1. Basic science (mathematics, physics, chemistry, biology).
2. Applied science (mechanics, thermodynamics, fluid mechanics, geology, circuit theory, properties of engineering materials, and so forth).
3. Applied engineering (for example, internal combustion engines, structures, machine design, industrial electronics, foundry technology, and plant design).
4. Administrative and managerial (cost control, industrial organization, labor relations, and so forth).
5. General (liberal courses, to provide a general educational background). Curricula may vary in the emphasis placed upon any group, and in the extent of dominance of one group over the others.

Historically, applied engineering courses dominated the curriculum in the early years. Gradually the pattern of basic science courses was evolved and generally included. Shop courses were reduced to a minimum. From 1885 until World War I, mathematics was stabilized in the older curricula, terminating with calculus. Since then only a few schools have carried the subject further in civil, chemical, mining, and mechanical engineering, while many schools have required additional mathematics in electrical engineering. Except in chemical engineering, and in some cases mining engineering, the amount of chemistry required has been limited to general inorganic chemistry.

The time requirement in physics has remained nearly constant in most curricula since about 1885. Generally, the classical approach to physics instruction has been followed. The depth has varied with the amount of mathematics available at each stage. Calculus, while standard in all curricula, is not employed to the same degree in physics. In civil and mechanical engineering the amount of physics is limited to one year in most schools; and in many the same limit is found in electrical and chemical engineering. Generally, however, the approach from the point of view of atomic and molecular structure is needed but wanting.

The time devoted to mechanics is similar in nearly all schools. The variation in effectiveness of the course is not due to allotted time so much as to the depth of instruction. For many years it was the custom to minimize the use of calculus in this subject. The development of stronger texts over the last two decades has greatly improved the effectiveness of the instruction; however, there is still much variation in depth of the requirements placed on the student. There may be said to be a definite upswing in the quality of instruction in mechanics, although this is not believed to be general. In mechanical engineering, for example, vibrations and their consequences are treated in only a few schools. In fact, in civil engineering dynamics is regarded as being unnecessary, yet fatigue is becoming more important in structural design.

Hydraulics used to be taught from the empirical standpoint. Between the two wars there was pressure, emanating from the aeronautics field, for instruction in fluid mechanics. Some schools dealt sincerely with this proposed change; but many others simply changed the course name from hydraulics to fluid mechanics.

While in chemical engineering thermodynamics has been taught with regard to interaction between the thermal and chemical circumstances involved, there has been little attention given to such matters in mechanical engineering. Today, a chemical engineer is not infrequently better trained for fundamental work in heat power than the mechanical engineer, in whose field heat power lies.

During the past several decades the instruction relating to engineering materials has developed into a program reciting a general discussion of their manufacture, and their mechanical properties as revealed by standard acceptance tests. The metallurgical aspects are touched upon lightly, if at all. Instances can be found of the absence of a course in materials in electrical engineering, while in other cases in the same field students get the notion that such instruction together with the mechanics of materials is largely unnecessary for an electrical engineer, especially in communications.

FACTORS OF MAJOR SIGNIFICANCE IN CURRICULUM DESIGN

MANY PERPLEXING PROBLEMS stem from the fact that the engineering college, in preparing students for professional work that will reach maximum culmination 20 or more years hence, must evaluate hazily discernable future events. It certainly appears desirable that a major stress be placed upon those elements of the curriculum that will give the most continuous and lasting support to the graduate's professional life. Apart from the teaching of the professional attitude toward engineering and the instilling of the engineering and scientific method of attack upon problems, there are certain specific features of the curriculum that can be accepted as most essential.

The first of these has to do with courses least likely to obsolesce. While it is necessary to give a certain amount of instruction relating to the present state of the art, it is certain that the present state will change, and hence that time given to such courses is not time devoted to a subject of sustaining value. Sifting back through the curriculum, it seems clear that instruction in the basic sciences, if taught in a manner such that knowledge of them makes available working tools, contributes the most sustaining part of the curriculum. Among these basic sciences, the greatest potential for future development in science and technology is to be found in mathematics. An engineer with a good knowledge of mathematics is in a position to read with understanding and profit in physics and chemistry. Likewise, as his interest and need may expand, he may read further in the applied sciences, such as mechanics, elastic stability, advanced thermodynamics, or fluid mechanics. Similarly, new applications of sciences to engineering situations may be understood and assimilated. Thus, mathematics not only becomes the support of the group of courses that will obsolesce least; it becomes the means of further technical growth as befits the graduate's interest and need. Building into the program in this and other means for further technical self-development of the individual after graduation is the second most important feature of a well-designed curriculum.

The third feature that impresses this committee as of ranking importance has to do with the way in which the applied courses are related to those in basic and applied science. Two distinct approaches are discernible in present practices: one utilizes the engineering situations provided in the applied courses to illustrate the manner of employing the sciences in engineering work, while the other makes the applied courses the goal of the curriculum with the minimum of application of the sciences. The former builds into the student a power of analysis and resolution in engineering situations that permits a wide range of application. The latter tends toward the achievement of a series of skills intended to equip the student for specific jobs immediately upon, and soon after, graduation. The first is professional preparation, the second vocational training. What is involved is not alone the way in which individual courses are presented; it especially relates to the prevailing concept of the function of the whole curriculum.

Following the concept that the differentiating characteristic of the engineering function is the ability to utilize the sciences for the creative process of design and development of useful apparatus, structures, or other works, the program should aim at the development and expansion of the imaginative process of creative thought. Engineering educational processes are most commonly of the problem type, requiring but a single answer, with no latitude for judgment, and no imaginativeness beyond the visualization of the circumstance of the problem. Programs in architecture far surpass those in engineering in this respect. We tend toward producing a literal-mindedness that is not compatible with creative imagination.

The foregoing discussion has been in broad terms. It is believed that quantitative specifications for engineering curricula are not adequate as guides to curriculum planning because they tend toward regimentation, toward fixation, and toward eventual stagnation of awareness of the professional needs. The content in each of the five categories enumerated here must be determined in terms of the need of the graduate two or three decades ahead, not in specific detail but in sound skeletal preparation, with most of the details to be filled in through further study and acquisition of experience in the field. The skeletal program must be strong and of sufficient stature to support and sustain the growing professional career.

Engineering is both a science and an art. A balance between both is desirable. The tendency has been to emphasize the art unduly. The "engineering approach" can be presented in the manner in which science is brought to bear on an engineering situation. Much of the art can better be acquired in the field. Industry is coming quite generally to recognize this arrangement as desirable for its needs.

SUGGESTED PROGRAM

The quality of engineering curricula varies over a wide range, from highly developed professional programs to those having a predominantly vocational content. The foregoing discussion relates especially to the middle and lower portion of the range. Accrediting procedures relate almost entirely to the minimum standards, and tend to breed complacency among those schools that just barely satisfy such a standard. While accrediting must be maintained as a part of the licensing procedure, it cannot be expected that accrediting of itself will achieve the improvement of schools that satisfy the minimum requirements—unless two or more classes of schools were established and accrediting set up for each class. The committee believes that such a scheme would be neither welcome nor desirable. Rather it believes that the engineering educational field has a great opportunity to study itself, with the object of finding ways at all levels to improve its service to the profession.

One way to make such a study is to set up an agency that would study and report its findings, as was done by the Society for the Promotion of Engineering Education in the 1920's, under the late W. E. Wickenden.[1] Such a procedure has the effect of isolating the study, and removing it from the schools themselves. The conclusions of Wickenden, written in 1929, are to be found in Appendix I of his report; and this committee is struck with the potency of the statement to today's situation, and the extent of the failure of the schools to implement much of the recommendations. Other statements, appearing since the Wickenden Report and bearing upon the same subject, are given in other publications.[2–5] From these it seems clear to the committee that what is now needed is active study and self-appraisal by the schools themselves, looking toward implementation of recommendations already made.

In some quarters the suggestion has been made that an overlay of graduate work is the answer to a need for stronger science content in the curriculum, and to a higher total level of achievement. The committee believes that the basic program in engineering leading to the first degree in the field should be of a quality to suffice for the professional need of perhaps 80 per cent of the graduates, and that truly graduate work should be reserved for the remaining few having special competence. The responsibility for support of the profession, it is believed, must rest chiefly upon the adequacy of the undergraduate program.

The great pressure upon the engineering schools to provide general education in addition to an increased scientific and technical training brings them constantly face to face with the limitation in time imposed by the conventional curriculum. It is perhaps time that this problem was approached in terms of total need; and then the time required to achieve this need be measured beginning with the preparation now available from the secondary schools. For many years the approach has been to see what can be given within the 4-year framework, with the result of overcrowding the program and with a general shifting first in one direction and then another without total gain in achievement. Other professions have had to face this issue. If engineering maintains professional stature, it will have to organize accordingly. Some have suggested a pre-engineering period in which the high-school preparation may be augmented, if necessary, to a desired level before beginning engineering study.

There has been some discussion of the list of degrees granted in engineering. There is a gradual tendency to drop the professional degrees of civil engineer, mechanical engineer, and so forth, awarded after a suitable interval of practical experience and the submission of an acceptable thesis. If the professional degrees became generally available for work in course, they could be used then to designate the longer programs that are now under way, whether they be 1-degree or 2-degree programs.

Finally, it becomes clear that there is going to be a shortage of engineers for many years to come. At such a time, in the national interest, it is of paramount importance that the best possible education in engineering be provided by our schools. Each man is going to be called upon to cover a greater range than heretofore, if the engineering needs are to be met. Every school should devote itself to ways of substantial improvement of its program, to the end that its graduates will meet the responsibilities being placed upon them.

REFERENCES

1. The American Scene, **W. E. Wickenden.** Society for the Promotion of Engineering Education (New York, N. Y.), volume I, 1929, page 1000.

2. Engineering and Social Progress, **Karl T. Compton.** *Proceedings*, Society for the Promotion of Engineering Education (New York, N. Y.), volume XLVII, 1939, page 8.

3. Atomic Engineering?, **Theodore von Kármán.** *Mechanical Engineering* (New York, N. Y.), October 1945, page 672.

4. Tomorrow's Engineers, **J. R. Van Pelt.** Excerpt from *Proceedings*, American Society for Engineering Education (New York, N. Y.), volume 55, 1948, page 168.

5. Present-day Engineering and Applied Science. Report of Panel on the McKay Bequest, Harvard University, Cambridge, Mass., 1950, page 7.

Steam-Turbine Electronic Regulator

Electronics now provides a static regulator with faster response than that obtained with the conventional hydraulic governor. The electronic governor gives a steady-state regulation of 0.5 per cent. The amount of overshoot when recovering from a transient condition has been reduced, and recovery time to a steady-state condition with sudden removal or addition of full load is limited to less than two per cent addition to the speed regulation. The basic part of the unit designed by Westinghouse Electric Corporation is a frequency network that detects the variation from the basic frequency and provides a signal voltage proportional to this deviation. This signal voltage is operated on by a stability network and amplified to control the solenoid cup valve—the connecting link between the hydraulic and the electronic systems. The solenoid cup valve controls the hydraulically operated steam-inlet valves.

The Application of Electric Motors in the Pulp and Paper Industry

J. A. TUDOR
ASSOCIATE MEMBER AIEE

D. M. PLATT

Using motors rated from a fraction of a horsepower up to 3,000 horsepower, the pulp and paper industry is driven largely by electric power. This article gives the method of determining motor requirements for some of the more important applications in this industry.

THE OUTPUT OF THE pulp and paper industry in the United States exceeded 24,000,000 tons in the year 1950, which is a 20 per cent increase in production over that of 1949.

One of the most important factors in producing paper is the electric power used in the mill. The drive requirements in a paper mill are extensive, ranging from small fractional horsepower motors to large grinder motor drives up to 3,000 horsepower. Here are two examples of the horsepower requirements in a paper mill:

1. A recently constructed West Coast 150-ton sulphate mill has a connected motor load of 11,500 horsepower.
2. A kraft mill in the southeastern United States has a 24-hour output of 600 tons and has a connected motor load of 23,000 horsepower; 43 per cent of the connected motor load is synchronous motors.

The purpose of this article is to describe some of the important motor applications, particularly in the wood fiber pulp and paper industry. Consideration is given to the method of determining the horsepower, speed, torque, voltage, and enclosure requirements for these applications.

The one raw material common to the various wood pulp and paper mills is logs. In the sulphate process hemlock, fir, and southern pine are the principal woods used. The sulphite process uses spruce, hemlock, and hardwoods; while groundwood pulp is made from hemlock, fir, and spruce.

The logs are transported to the mill by truck or rail, or are towed as rafts in navigable waters. At the mill they are received in a pond or sorting basin from which they are carried by a log haul into the mill; see Figure 1. From the log haul, the logs are barked by drum barking, cutter head barking, or the more recently developed high-pressure hydraulic method.

At this point, the groundwood process differs from the chemical pulp process. The cants or blocks are delivered to either pocket or magazine-type grinders where large grinding stones tear off the wood fibers. The resultant mixture of fiber and water is pumped to screens, and from there to a wet lap machine or a thickener (dehydrator), and on to the beaters.

In the sulphate and sulphite processes, pulp is obtained by chipping the barked logs and then cooking the chips in a large vessel called a digester. The sulphites are cooked in sulphurous acid and calcium bisulphite with free sulphur dioxide; whereas, the sulphate pulp is digested with caustic soda and sodium sulphide. After the chips are digested the pulp is washed to remove the cooking liquor. Next it is screened and the dirt is removed, and then it is pumped to the beaters for further refining.

From the beaters, the mechanical and chemical pulp proceeds through pumps and stock chests through Hydrafiners, Jordans, and screens to the Fourdrinier section of the machine. On the Fourdrinier the sheet is formed by

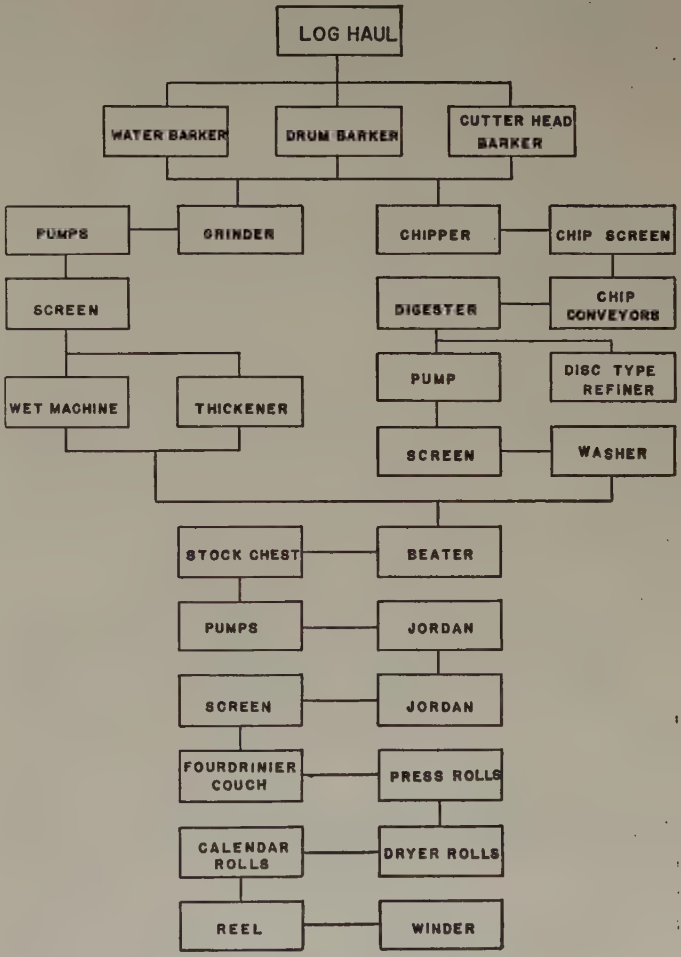


Figure 1. Flow diagram of pulp and paper production

Essentially full text of a conference paper recommended by the AIEE Committee on General Industry Applications and presented at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951.

J. A. Tudor is with the Westinghouse Electric Corporation, Portland, Oreg., and **D. M. Platt** is with the Crown Zellerbach Corporation, Camas, Wash.

draining away vast amounts of water to increase the consistency of the mixture from a thin liquid at about 0.3 per cent to a pulp web of roughly 40-per cent consistency. The sheet of paper is made by passing the sheet through presses and dryers for further water removal. The sheet is smoothed out and given the desired finish on the calenders before the sheet is reeled into large rolls of paper.

Rewinding and further processing (which will not be discussed in this article) is done before shipping the finished product to the customer.

LOG HAUL

Generally a log haul is composed of one or more special chains driven along a steel-lined trough. The chain has special chair links which push the log up the inclined trough to the cutoff saw. Usually the log haul is driven by an a-c motor through a speed reducer to obtain a chain speed of 75 to 150 feet per minute.

Most commonly used on a log haul is the wound-rotor motor ranging in size from 10 to 100 horsepower. The wound-rotor motor is used to obtain speed control and high starting torque. Sticking of the log haul chain and general heavy drag is encountered because of heavy irregular logs. Cold weather operations often result in frozen chains, requiring high-torque starting to break away the iced parts. The horsepower required to operate the haul is determined as follows:

$$HP_1=\frac{f's'(W)\cos\theta}{33{,}000\,e}+\frac{s'W\sin\theta}{33{,}000} \tag{1}$$

where W=weight of maximum number of heavy run logs on log haul in pounds; f'=coefficient of friction, 0.4; s'=speed of log haul in feet per minute; e=mechanical transmission efficiency, 0.85; and θ=angle of slope from horizontal—based on straight line drawn from water line to horizontal portion of log haul.

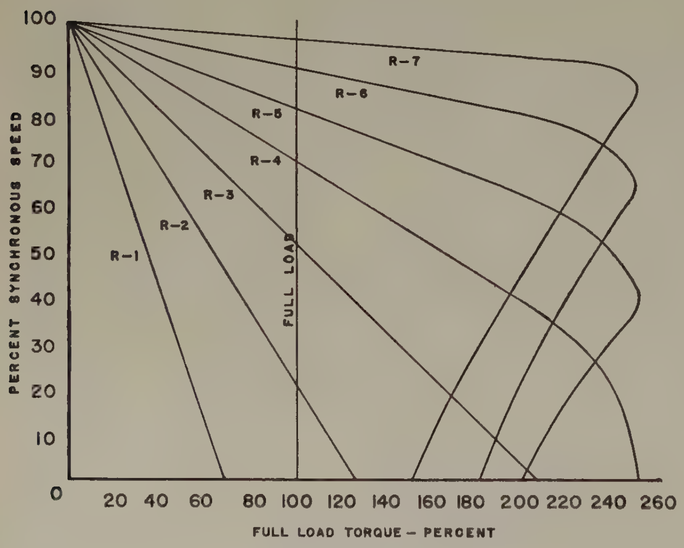


Figure 2. Typical speed-torque curve for a wound-rotor induction motor

Wound-rotor hoist-type motors have starting torques of 250 per cent or more. The speed torque curves for different values of resistance in the rotor controller appear as in Figure 2.

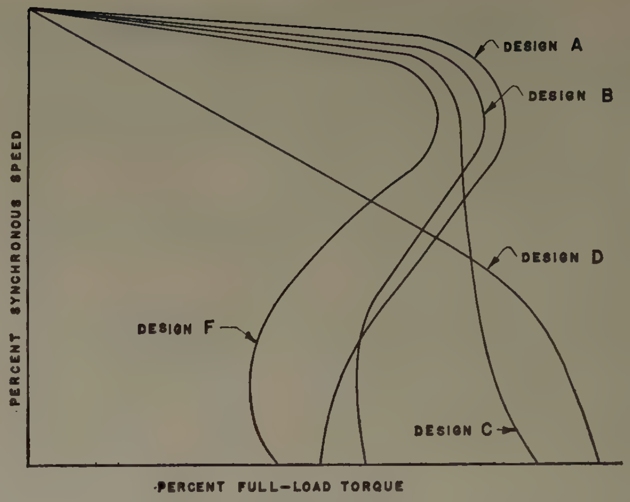


Figure 3. Typical speed-torque curves for a squirrel-cage induction motor

The wound-rotor motor usually selected for this operation is of the dripproof enclosure type. A very good enclosure for this application is the totally enclosed fan-cooled motor. This enclosure protects the windings from the weather, grease, water, chips, and bark.

The controls used have to be versatile. Magnetic motor primary control, push-button operated, with manual motor secondary controller and resistor provide the operator with adjustable starting torque and multiple-speed running points. An electrically operated brake is required on log hauls where $W\sin\theta > W\cos\theta f'$. When the force of the log in the slide direction is greater than the weight of the log times the cos θ times the coefficient of friction of the logs on the chute, the logs will slide back into the pond. A brake with a holding torque of 70 per cent of rated motor torque is usually all that is required.

On light log hauls squirrel-cage National Electrical Manufacturers Association (NEMA) *D* motors, as shown in Figure 3, may be used successfully. The horsepower calculations are the same as in equation 1.

One other computation should be made to check the motor horsepower selected by equation 1: thermal horsepower or rms horsepower is determined as follows:

$$\text{rms } HP=\frac{\sqrt{(2HP_1)^2 t_{\text{start}}+HP_1^2 t_{\text{run}}}}{t_{\text{start}}+t_{\text{run}}+t_{\text{rest}}/2} \tag{2}$$

where HP_1=horsepower calculated by equation 1; and t=time in seconds to start, run, or rest as noted.

Twice *HP* is used for starting to give a representative heating value. If the rms *HP* is adequate, the motors will not heat on this application.

Also if more than five starts per minute are anticipated (very abnormal) the motor manufacturers should be advised. The duty cycle check for thermal adequacy should be made for a period of not less than 1 hour.

CHIPPER MOTOR

The next application of significance is the chipper drive.[1] Chipper size usually is selected so that all

Table I. Power Requirements for a Chipper

1 Disc Diameter, Inches	2 Spout Diameter, Inches	3 Speed, RPM*	4 WR^2 Disc, Pound-Feet^2	5 Cutting per Full Cut**	6 Power per Knife		7 Production per Knife Cords per Hour		8 Optimum Log Diameter, Inches
					Peak***	Continuous****	Peak	Continuous	
54	12	600	10,000	85	123	49	17.6	7.0	7.6
84	14	450	35,000	115	125	50	17.9	7.2	8.9
88	18	400	55,000	191	184	74	26.4	10.5	11.4
96	22	360	80,000	285	248	99	35.4	14.2	13.9
110	26	300	150,000	398	288	115	41.0	16.5	16.4
150	34	277	1,000,000	681	455	182	65	26	21.5
175	42	240	2,000,000	1,040	602	240	86	34	26.6

* Maximum permissible operating speeds.

** Based on 3/4-inch chips and log diameter equal to spout diameter.

*** Based on motor with 250-per cent pull-out torque.

**** Based on hemlock wood requiring 7 horsepower-hours per stacked cord.

but the largest logs will go into the spout without being split or sawed into cants. The chipper must maintain the required rate of production with a run of average size logs. To vary the production rate the number of knives can be varied, for chippers are manufactured with 2, 3, 4, 6, 8, 10, or 12 knives. It is very seldom that a chipper is operated below its rated speed.

In applying a motor to a chipper it is necessary first to determine the maximum horsepower which the motor must develop. The maximum peak load occurs with the largest log. For a hemlock log with a given size of spout, the power required can be obtained from column 6 of Table I by multiplying by the number of knives. The continuous power required is shown in column 6, using optimum log diameter, column 8. Table II shows the relative number of horsepower hours required per stacked cord for different species of wood.

Motors are nearly always chosen with 250 per cent pull-out torque, 40 per cent starting torque, and 50 to 80 per cent pull-in torque. The higher pull-in torque assures shorter starting time. When starting, the only drag is caused by the static friction of the bearings after breakaway, and the running torque drops to a low value during the accelerating period.

While accelerating the chipper disc, an amount of heat is developed in the rotor windings approximately equal to the kinetic energy of the rotating parts at full speed. In a wound-rotor motor this heat can be dissipated partially in external resistors; in the synchronous motor or induction motor the heat must be absorbed by the motor rotor.

To drive the smaller chippers (up to about 84 inches) belted induction motors normally are used. From 84- to 110-inch diameter chippers may be driven by belted induction motors or engine-type synchronous motors. Above the 110-inch diameter chippers, synchronous motors are used. The synchronous motor is superior to the induction motor in that the production of chips is constant and does not drop off with load. The same advantage of the synchronous motor is a disadvantage on power peaks, for the synchronous motor does not lose speed to allow the stored energy in the rotor and disc to carry the peak loads. Thus the induction motor makes a smoother load on the power system of the plant. On long logs, however, the induction motor must drive the chipper through part of the log as the stored energy is not sufficient to carry through. This disadvantage may outweigh the advantage for the induction motor.

The motor must be able to withstand high shock on bearings and stator and the insulation must be able to withstand dirt and moisture. The windings must be braced adequately to withstand high starting currents and repeated high currents near pull-out when chipping heavy logs. Special chipper motors have been designed and have had sufficient service to prove themselves for this tough application.

CHIP CONVEYORS

THE POWER REQUIRED to run conveyor belts can usually be obtained from the manufacturer of such equipment and any power formulas obtained as based on experience, judgment, and quality of conveyor equipment.

The power requirements are divided into three parts: 1. power to run the empty belt; 2. power to move the load horizontally; and 3. power to change elevation of the load—positive if it goes up and negative if down.

$$\frac{[(W_b+W_l)f'\pm(W_l\sin\theta)]s'}{(33{,}000)e}=HP \tag{3}$$

where W_b=weight of belt; W_l=weight of load; θ=angle of belt travel from horizontal; $W_l \sin\theta$ is negative if the slope is down and positive if the slope is up, based on direction of belt travel; s'=speed in feet per minute; e=efficiency of power transmission, use 0.80; and f'=coefficient of friction, 0.03.

The motor selection for conveyors should be based on the type of atmosphere—where it is unusually dusty and dirty a totally enclosed fan-cooled motor should be used. This enclosure protects the motor windings from damage due to moisture, oil, dust, chips, chemical powders, and corrosive fumes. Dripproof or splashproof enclosures are used for general nondirty applications. NEMA class-*C* high-starting torque motors normally are used. NEMA class-*B* normal-starting torque motors can be used for any general conveyor where there is little tendency for conveyor dragging or sticking. This class of motor is a standard general-purpose motor and is a flexible type of unit to use in a plant because of interchangeability.

PUMPS[2,3]

WATER IS USED in large quantities in all of the processes of producing pulp and paper. Water is used to

Table II. Energy Requirements for Various Kinds of Wood

Species	Horsepower-Hours per Stacked Cord	Per Cent of Hemlock
Hemlock	7.0	100
Yellow pine	6.1	87.1
Gum wood and poplar	10	142.8
Oak and other hardwood	12.3	175.7

Table III. Power Requirements for a Fourdrinier Machine

	Recommended Constants HP per Inch Width per 100 Fpm	
	NRL	RDC
Couch		
Paper Classification		
Toweling and light wrapping	0.043	0.050
Glassine and bond	0.064	0.075
News, kraft, and book up to 1,200 fpm	0.064	0.075
News, kraft above 1,200 fpm	0.086	0.100
Main Press Sections: Plain or Suction Type		
Pair of main rolls	0.0225	0.030
Top roll only		0.010
Top side roll		0.010
Dual press side rolls each	0.020	0.025
Smoothing Press—Marking Press		
Pair of rolls	0.009	0.012
Size Press		
Pair of rolls	0.015	0.025

Note 1: Recommended power constants for presses are on the basis of a maximum nip pressure of 175 pounds for linear inch.

Note 2: Power constants for size presses have been increased from 0.009 to 0.015 based on test data from presses individually driven.

	Recommended Constants per Dryer Roll Above 160 Fpm HP per Inch Width per 100 Fpm	
	NRL	RDC
Dryer Sections		
60-inch diameter rolls	0.0018	0.0027
48-inch diameter rolls	0.0014	0.0021
42-inch diameter rolls	0.0013	0.0019
36-inch diameter rolls	0.0011	0.0017

Note 1: Power constants for a dryer section should be based on the total number of dryer rolls in the section including both paper and felt dryers.

Note 2: Starting torque for breakaway on dryers equipped with plain sleeve bearings has been considered by electric equipment manufacturers previously as $4^1/_2$ times normal running torque as determined by the NRL constant. Some new machines built since the war and old machines rebuilt have required as high as eight times NRL torque to start dryers with plain bearings. For antifriction bearings torque of three times NRL torque is ample.

Note 3: The dryer NRL power constants in the foregoing are based on either antifriction or sleeve bearings above 160 feet per minute. When sleeve bearings are employed below 160 feet per minute, the running load increases rapidly. The following multipliers should be applied to both NRL and RDC constants in estimating the operating power requirements, interpolating as required.

Fpm	Multiplier
200	1.00
140	1.26
120	1.51
100	1.80
80	2.16
60	2.54
40	3.04

Note 4: For cooling or sweat dryers, since the water is frequently carried in the rolls, the power constants should be multiplied by 1.33.

Note 5: Cleaning doctors required additional power per blade as follows: 0.00075 HP/inch width/100 fpm based on a pressure of 1 pound per inch width which is approximately correct if there is no loading other than the weight of the doctor itself.

	HP per Inch Width per 100 Fpm	
	NRL	RDC
Breaker Stack		
Pair of rolls	0.009	0.012
Calender Stacks 8 and 9 rolls; Paper Classification; Weight per Ream (500 Sheets 24×36 inches)		
up to 70	0.035	0.050
up to 90	0.056	0.060
up to 130	0.056	0.080
up to 225	0.056	0.100
above 225	0.056	0.120
Reels		
up to 125 pounds except kraft	0.008	0.012
above 125 pounds except kraft	0.008	0.020
all kraft	0.008	0.020

wash the logs, hydraulically bark them, assist in digesting chips, and reduce the consistency of the digested pulp. A survey of a number of mills has shown the pump load to be 10 to 20 per cent of the total mill load. Individual pump motors in the mills will vary in capacity from 5 to 1,250 horsepower and larger and with speeds of 720 to 3,600 rpm.

Centrifugal pumps have been designed to handle stock of 5-per cent consistency and higher and these pumps are suitable for most of the stock and all of the water requirements.

The following tabulation gives a good idea of the fresh water requirements of different types of pulp and paper mills.

Product	Water Requirements (Gallons per Ton)
Mechanical pulp	20,000
Kraft pulp	35,000 to 40,000
Unbleached sulphite pulp	55,000
Soda pulp	90,000
Paper formation (making use of white water)	2,000 to 2,500

General-purpose squirrel-cage motors with normal starting torque (NEMA *B*) are suitable for this constant-speed service and usually the motors are direct-coupled to the pump shaft.

Vertically mounted pumps usually are used for well or river water and for waste disposal.

Most pumps used in paper mills are the single-stage centrifugal type. Multistage centrifugal pumps are used where high-pressure water (200 to 1,400 pounds per square inch) is required.

In selecting a pump to lift water from one level to another, it is necessary to determine the total pressure or head in feet which must be developed by the pump. This total head is the sum of the gravity head and friction head. The gravity head is the distance required to lift the water and the friction head is the head equivalent to the loss in pressure due to the flow in the pipe and varies with the velocity of the water and the size and condition of the pipe. A small percentage of head should be added for the pressure drop in elbows and valves.

Equation 4 is fairly accurate and can be used to determine pressure loss in pipes.

$$h_f = f\,\frac{l}{d}\,\frac{v^2}{2g}\text{ feet} \qquad (4)$$

where h_f=friction loss in water, head-feet; f=friction factor (a good mean value for cast iron pipes is 0.02); l=length of pipe in feet; d=internal diameter in feet; v=velocity of water in feet per second; and g=32.2 feet per second squared.

Losses due to bends are given by

$$h_b = C_b\,\frac{V^2}{2g}\text{ feet (pressure loss)} \qquad (5)$$

Values of C_b (d is the diameter of the pipe and r is the radius of the bend in feet) are

d/r	0.2	0.4	0.6	0.8	1.00
C_b	0.131	0.138	0.158	0.206	0.294

Diameter of pipe (feet) required to deliver Q cubic feet of water per second under a head of h feet if the friction factor is f is given in equation 6.

$$d=\sqrt[5]{\frac{fl}{2gh}\,\frac{(4Q)^2}{(\pi)}}\text{ feet} \qquad (6)$$

where l=length of pipe in feet; and g=32.2 feet per second squared. (1 cubic foot per second equals 448.8 United States gallons per minute.)

From equations 4, 5, and 6 the normal head losses in straight flow and bends can be determined. Also the size of pipe can be determined from these equations; therefore the motor horsepower can be determined by equation 7.

$$HP=\frac{(h_{\text{lift}}+h_b+h_f)V\text{ cubic feet per second }62.3\text{ pound per cubic foot}}{550\text{ foot pounds per second per horsepower }e} \qquad (7)$$

where e=efficiency of pump estimated at 65 per cent but best value can be obtained from manufacturer's test data.

In addition to the stock and water pumps, large capacity vacuum pumps are required. A vacuum is created in the flat boxes which are mounted under the Fourdrinier wire and in the couch roll of the Fourdrinier-type paper machine. Vacuum boxes also are installed in certain of the auxiliary rolls used in the forming section of cylinder machines. They also are applied in certain cases on the main press felt in press rolls where suction presses are applied. There are two general types of vacuum pumps, rotating and reciprocating. The most common is the rotary type. Individual units range from 50 to 300 horsepower with speeds from 250 to 600 rpm. The starting torque requirements are low and the operating load is steady. General-purpose squirrel-cage motors (NEMA *B*) are suitable for belted service to the higher speed units. Synchronous motors are frequently used on the main press felt and in press rolls where suction pressures are applied. Synchronous motors are recommended for this service using either direct-coupled, belted, or engine-type mounting. Less than 100-per cent pull-in torque is satisfactory on these units because the vacuum normally is broken before starting.

Estimated power requirements for vacuum pumps vary from 3 to 4 horsepower per ton of daily capacity.

PAPER MACHINE POWER REQUIREMENTS

With the development and application of sectional electric drives for paper machines, the power required for each section has been and can be measured readily.

Both The American Pulp and Paper Institute and AIEE have worked together to develop power constants based on the power required per inch of width of wire and per 100 feet of speed per minute. These constants cannot be considered rigid and can vary as much as 2-to-1 depending on many factors such as bearing friction, steam seal friction, and so forth, but they do have a practical use in assisting the paper machine manufacturer and the paper maker.

Table III is for Fourdrinier-type paper machines other than those producing tissue. The constants are given as NRL (normal running load) constant which is based on expected operating load of each section when operated under normal conditions, and RDC (recommended drive capacity) constant which represents the power requirements for any particular section when operated at the maximum load to be anticipated.

In calculating the rating of a single motor, turbine- or engine-drive, 15 per cent should be added for transmission losses. Also, input should be calculated at maximum and minimum speed to obtain the increase in torque requirement for low-speed operation.

These power constants are being reviewed constantly and even at this writing they may be in the process of revision.

Motor power requirements for making paper are high and the individual applications vary over a broad range. Each process can be studied individually and the motor power requirement solved simply.

With the aid of the equations and tables set down in this article the motor horsepower requirements for the log haul, chipper conveyors, pumps, and Fourdrinier paper machines can be calculated readily.

REFERENCES

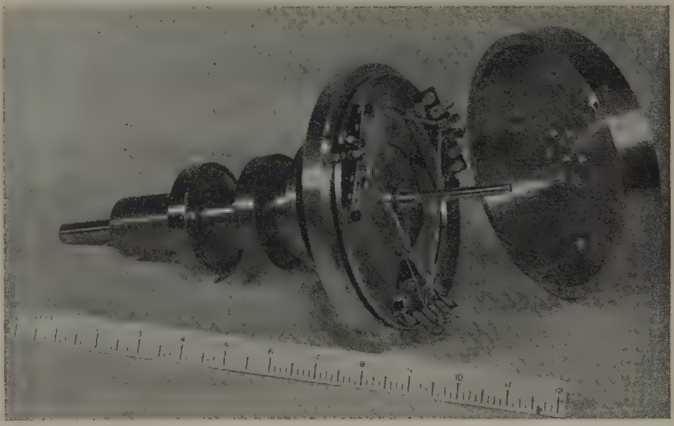
1. The Application of Synchronous and Induction Motors to Chippers, **R. R. Baker, M. R. Lory.** AIEE *Transactions*, volume 66, 1947, pages 1070–7.

2. Pulp and Paper Industry, **R. R. Baker.** *Westinghouse Electric Corporation* (East Pittsburgh, Pa.), August 1946.

3. The Engineer's Manual (book), **Hudson.** John Wiley and Sons, New York, N. Y., second edition, 1939.

4. Power Requirements for Paper Machines. Committee Project Report, A. S. Goodrich, Chairman, The American Pulp and Paper Institute Engineering Division.

NBS High-Speed Crystal Clutch



An experimental crystal clutch developed at the National Bureau of Standards (NBS) is believed to be the first of its type. In the new clutch, shown unmounted, with cover plate removed, three Bimorph piezoelectric crystal elements bend when a direct voltage is applied. This bending pinches the clutch output disc between the rotating mounting plate and the rotating crystal pressure plate. Suited to certain instrumentation applications, the clutch is characterized by high speed of response and negligible current drain. No current flows other than insulation leakage after the applied voltage has charged the capacity of the crystals. Useful torque is delivered by the output shaft in 0.2 millisecond after applying the exciting voltage

Cable Through Mountain Tunnel Links Power Systems

F. M. WILSON
MEMBER AIEE

R. A. NELSON
ASSOCIATE MEMBER AIEE

THE 69-KV gas-filled pipe-type cable circuit through the Adams Tunnel under the Continental Divide is an integral part of the transmission link between power systems on the eastern and western slopes of the Rocky Mountains.

On the basis of competitive bids the cable circuit through the tunnel was constructed in lieu of a transmission line over the mountains, which would have crossed the 11,850-foot Buchanan Pass.

The 13.1-mile-long Adams Tunnel, which pierces the backbone of the continent, is a major link in the vast Colorado-Big Thompson Project in northern Colorado and was constructed to carry diversion water from the western side of the Rocky Mountains to the eastern side for purposes of irrigation and power development.

The circuit consists of three single-conductor cables housed in a $5^{9}/_{16}$-inch outside-diameter steel pipe which is mounted to the top of the circular 9.75-foot-diameter tunnel above the normal water surface. Near each end of the tunnel the pipe is brought out through vertical shafts to cable spreaders, which are connected by copper tubes to single-conductor potheads.

Protection of the pipe against corrosion is provided by a 5/32-inch minimum thickness submarine-type coating consisting of coal-tar enamels and two wrappings of Fiberglas.

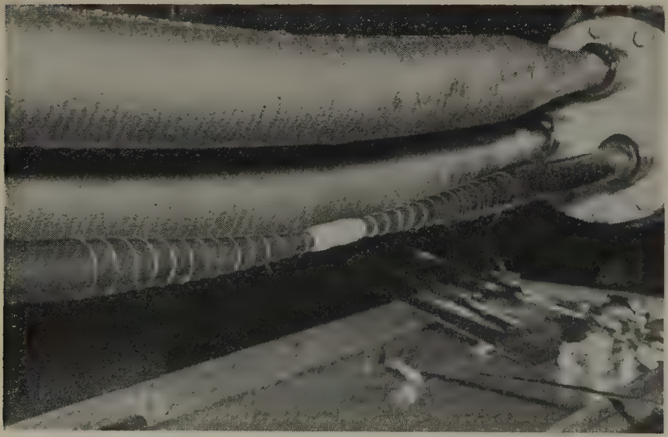


Figure 1. Comparison of stepped-down insulation and completed insulation at cable splice

From a mechanical standpoint the installation is unique because the pipe is anchored and prestressed so that stresses due to wide variations in temperatures are taken by the pipe without movement. The pipe is anchored at approximately 1,000-foot intervals and supported at about 20-foot intervals throughout the length of the tunnel. Prestressing was accomplished by stretching each section of pipe to its normal length at 103 degrees Fahrenheit by means of adjustable stud bolts through brackets on the anchors which are threaded into collars welded to the pipe. This arrangement required extreme accuracy in locating the collars welded to the pipe so that they came within the anchor brackets in the proper position. To resist corrosion and to eliminate the need for a protective coating the pipe anchors were cast from 410 stainless steel and the pipe collars and hangers were cast from 18-8 stainless steel.

Semistop joints are provided in the pipe about 925 feet from each end of the horizontal run inside the tunnel and at intervals of approximately 2,686 feet thereafter. Cable splices are made at these joints. By-pass piping and valves are provided at the semistop joints for gas control.

Access to the tunnel through the gatehouse at the west portal was limited to the entrance of men and small tools and equipment. This required construction activities to be carried on primarily by access through the east portal of the tunnel. All operations inside the tunnel required very careful co-ordination because of the limited space for working and for transporting men, materials, and equipment in and out of the tunnel. This limitation, together with the difficulty of access, made it necessary to do as much work as possible outside the tunnel. An oiled road approaching the east portal of the tunnel was selected as the working area for welding the pipe into approximately 1/2-mile sections and for pulling the cable into these sections.

After the cables were pulled, the sections of pipe were loaded on dollies spaced about 40 feet apart and hauled into the tunnel by a tractor. After the west end was secured to the tunnel arch the remainder of each pipe section was wedged upward into place by a system of rubber rollers mounted on top of the tractor and on top of a rolling frame pushed about 40 feet ahead of the tractor. The half-mile lengths of cable were joined inside the tunnel by splices which were enclosed by 10-inch sleeves welded to the pipe. Figure 1 shows a splice being made.

After the installation was completed a 3-phase 60-cycle 120.75-kv test for four hours was made simultaneously on the three single-conductor cables by using generating facilities at the Estes Power Plant. At the test voltage, which was limited by the equipment at Estes rather than by the cable insulation, the charging requirement of the cable circuit was 22,000 kva.

The attenuation losses of the cable circuit measured from the potheads at the east portal to the potheads at the west portal were found by tests conducted by the contractor to be 27.2 decibels on the *A* phase to ground and 27.4 decibels on the *B* phase to ground at 50 kc.

Digest of paper 51-293, "Cable Through Tunnel Under Continental Divide Links Power Systems," recommended by the AIEE Committee on Insulated Conductors and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

F. M. Wilson and **R. A. Nelson** are both with the Bureau of Reclamation, Denver, Colo.

Oil Circuit Breaker for 7,500,000-Kva Service

F. B. JOHNSON
MEMBER AIEE

R. E. FRIEDRICH
ASSOCIATE MEMBER AIEE

A NEW DESIGN of high-voltage dead-tank type of oil circuit breaker has been developed for 230-kv service and above which requires a minimum amount of oil with the attendant simplification in methods of oil handling and maintenance procedures, while still retaining the advantages of the time-proved round tank construction. This circuit breaker culminates a period of intensive development over the past ten years during which, in the 230-kv class, the ratio of kilovolt-amperes interrupted per gallon of oil has increased by over 11 times.

The amount of dead-space oil has been reduced by a radical redesign of the tank which takes a shape resembling that of a watch case. Figure 1 shows the new tank superimposed on the equivalent round tank which illustrates the amount of excess volume that was eliminated. The same minimum electrical clearances as in the round tank are maintained so that the new form passes successfully all voltage tests required of the more conventional shape. The circuit breaker also performed well on all standard design tests including temperature rise at rated current.

The tank consists essentially of a bottom section formed by welding together two halves of a single dome and attaching thereto a conical-shaped member of elliptical cross section which tapers upward to enclose the bushing-current transformers, pole unit levers, and so forth, with a minimum of wasted space. This design obtains mechanical strength from the inherent stiffness of the dome sections comprising the bottom and from a slight increase in thickness of the steel. It readily withstands, without deformation, the same hydrostatic pressure test of 150 pounds per square inch made on conventional design tanks. Likewise, it has been demonstrated in the High Power Laboratory at East Pittsburgh, Pa., that the closely fitting tank shape is entirely adequate to sustain the pressure shocks accompanying interruption of currents well above the rating of the circuit breaker and possibly serves to reduce the external demonstration caused by the downward traveling pressure shock wave in the oil because of the curvature of the tank bottom.

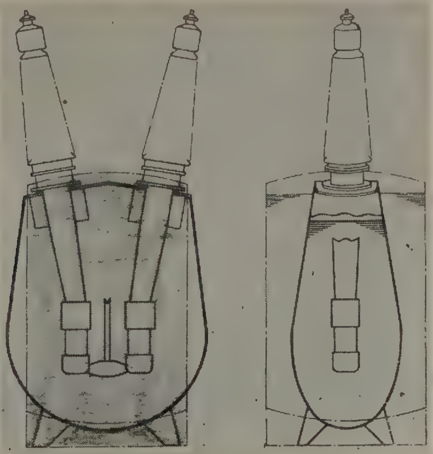


Figure 1. New design oil circuit breaker superimposed on round tank circuit breaker of comparable rating showing regions of excess oil eliminated

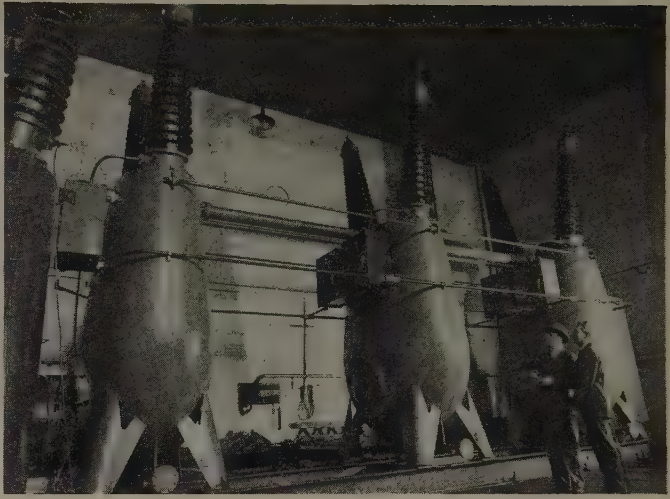


Figure 2. New design 230-kv 7,500,000-kva oil circuit breaker set up for fault-interrupting tests in High Power Laboratory, East Pittsburgh, Pa.

This circuit breaker is equipped with the latest refinement of the multiflow De-ion grid similar to that used in the 10,000,000-kva circuit breakers installed at Grand Coulee and described in detail in other Institute papers.[1,2] In a series of tests on a 3-pole assembly shown in Figure 2, the 7,500,000-kva interrupting capacity was demonstrated. Single-phase tests were made at normal line-to-ground voltage of 132 kv up to the 3-phase equivalent of 4,800,000 kva, by half-pole tests at 66 kv to 8,500,000 kva, and by factor-of-safety tests at 44 kv to a maximum fault current corresponding to 11,500,000 kva. A number of 3-phase fault interruptions were made to a maximum of 2,750,000 kva. This is believed to be the highest power 3-phase test ever made at 230 kv in laboratory or field.

Adequate insulation even during the period in which the gas bubble resulting from the arc is located in the electrostatic field is evidenced by overvoltage fault-interrupting tests with the voltage maintained across the circuit-breaker terminals for considerable lengths of time following interruption.

REFERENCES

1. High-Voltage Oil Circuit Breakers for 5,000,000 to 10,000,000 Kva Interrupting Capacity, **W. M. Leeds, R. E. Friedrich.** AIEE *Transactions*, volume 69, part I, 1950, pages 70–6.

2. Interrupting Capacity Verification of 10,000,000-Kva 230-Kv Oil Circuit Breakers for Grand Coulee Power Plant, **A. F. Darland, W. H. Clagett, W. M. Leeds.** AIEE *Transactions*, volume 70, part II, 1951 (*Proceedings T1-257*).

Digest of paper **51-314,** "New Design Oil Circuit Breaker for 7,500,000-Kva 230-Kv Service," recommended by the AIEE Committee on Switchgear and approved by the AIEE Technical Program Committee for presentation at the Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

F. B. Johnson and **R. E. Friedrich** are both with the Westinghouse Electric Corporation, East Pittsburgh, Pa.

Evaluation of Manual Methods of Resuscitation

A. S. GORDON MAX SADOVE FRANK RAYMON A. C. IVY

Six methods of resuscitation are described, and the results are compared with respect to lung ventilation, circulatory effects, rate of performance, and performance aspects.

THE ADEQUATE evaluation of manual methods of artificial respiration has been hampered by the inability to produce prolonged periods of apnea during which a group of methods could be appraised comparatively on the same subjects. Previous studies in the laboratory at the College of Medicine of the University of Illinois have used fresh corpses and normal subjects with passively suspended respiration to obtain such data. However, vital circulatory processes cannot be studied on the former and, it is generally agreed, the latter give inaccurate results because the conscious subject can assist or resist the manual maneuvers.

A method of producing drug-induced apnea for prolonged artificial respiration studies on normal human volunteers has been perfected here. This is accomplished by the use of intermittent injections of intravenous pentothal sodium and curare drugs. The former produces sleep and an amnesia for the procedure, whereas large enough doses of the curare drugs temporarily paralyze all of the skeletal muscles of the body, including the diaphragm and respiratory muscles. In this state, a subject is provided who is unconscious and unable to breathe and thereby closely resembles one who actually requires artificial respiration.

Using this technique on 50 normal healthy adult males, a number of manual methods and the Eve rocking method have been studied.* Studies have included an evaluation of (1) lung ventilation; (2) circulatory effects; (3) fatigue of the operator; (4) rate of performance; and (5) pedagogical and performance aspects.

METHODS OF ARTIFICIAL RESPIRATION STUDIED

THE METHODS OF resuscitation studied included the commonly employed and the newer manual methods, see Figure 1. The Eve rocking method is, strictly speaking, a mechanical method but was evaluated here because it lends itself readily to these studies and further comparative data on this method are useful. On one group of the volunteers the pole-top method of resuscitation also was studied. All methods were applied to all subjects in each group in order to provide comparative data. In this study, all methods were performed at a rate of 10 to 12 complete cycles per minute.

Schafer Method (*Modified*): The standard Schafer prone pressure method utilizes pressure on the flanks over the floating ribs of the prone subject to induce active expiration; with release of pressure inspiration occurs passively. The use of "back pressure," in which the pressure is applied over the mid-back (just below the shoulder blades) with the fingers spread and the thumbs about 1 inch from the spine, has been found to give almost twice as much ventilation as standard prone pressure. Accordingly, in the Schafer method and all other prone manual methods this back-pressure technique was applied.

Arm-Lift Chest-Pressure (*Silvester*): This century-old method is performed with the subject in the supine position. The arms are grasped above the wrists and drawn first upward and then above the victim's head until they touch the floor. Then they are brought back to the chest and pressure is exerted in a downward direction.

Eve Rocking Method: In this mechanical method the victim is placed prone on a stretcher and alternately rocked 45 degrees in a head-down position and then 45 degrees in a feet-down position.

Arm-Lift Back-Pressure (*Nielsen Method*): The Danish Nielsen method is applied to the subject who is lying prone with both hands resting under his face. The arms are grasped above the elbows and lifted until firm resistance is met. This induces active inspiration. Then they are replaced and back pressure is exerted to cause active expiration.

Hip-Lift Back-Pressure Method: In this method, the operator places his hands beneath the hips of the prone subject. The hips are lifted 4 to 6 inches, which results in active inspiration, and then are replaced on the ground. Back pressure then is exerted to cause active expiration. A variation of this technique is the hip-roll back-pressure method in which the subject is "rolled" up onto the operator's knee or thigh, followed by back pressure.

Pole-Top Method: This method is used for immediate resuscitation of linemen who are shocked while working on the pole tops. The rescuer ascends the pole and places the victim astride his own safety belt. He then rhythmi-

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*Detailed accounts of these studies are to appear in: Journal of the American Medical Association, Journal of Applied Physiology, and American Journal of Physiology.

Full text of paper 51-378, "Evaluation of Manual Methods of Resuscitation," recommended by the AIEE Committee on Safety and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

A. S. Gordon, Max Sadove, Frank Raymon, and **A. C. Ivy** are all with the University of Illinois College of Medicine, Chicago, Ill.

Table I. Lung Ventilation with Various Methods of Artificial Respiration on 26 Normal Adult Healthy Male Volunteers Rendered Unconscious and Totally Apneic with Pentothal and Curare Mixtures

Method* (All Performed at Rate of 10 to 12 Complete Cycles per Minute)	Tidal Volumes (Cubic Centimeters per Complete Respiratory Cycle)
Schafer (back-pressure with spring-off)	485
Eve rocking**	751
Hip-roll back-pressure	967
Arm-lift back-pressure	1056
Arm-lift chest-pressure†	1069
Hip-lift back-pressure	1140
Pole-top method††	725

* 26 cases, except where noted. ** 10 cases only. † 15 cases only. †† 5 cases only.

cally compresses the victim's abdomen with both hands while he is being lowered to the ground for definitive care.

RESULTS

Lung Ventilation (see Table I): All of the "push-pull" methods (arm-lift back-pressure, hip-lift back-pressure, hip-roll back-pressure, and arm-lift chest-pressure) which use a double maneuver resulting in active inspiration and active expiration are two to three times as efficient in getting air in and out of the lungs as the Schafer method. This occurred despite the fact that, in this series, the Schafer method was performed with back pressure and a spring-off or quick release at the end of the pressure in order to give greater ventilation than with the standard Schafer prone pressure. The Eve rocking method (mechanical) gave values intermediate between the Schafer and the push-pull manual techniques. The Silvester (arm-lift chest-pressure) method gave values as great as the better prone methods; however, previous tests have shown that in over one-half of the cases the tongue falls back into the throat and prevents air from reaching the lungs.

The pole-top method was shown to give adequate ventilation and should be applied immediately in case the victim is on a pole. However, he should be lowered to the ground and one of the push-pull methods started as soon as possible, since his position on the pole will impede circulation due to the pooling of blood in the dependent parts of the body.

Circulatory Effects: Although getting air in and out of the lungs remains the prime goal of artificial respiration, it is important to know how much oxygen passes into the blood in the lungs and is carried to the body cells. In 15 subjects whose respirations had been stopped with drugs, each method was performed for 15 minutes. Blood specimens were drawn during and at the end of the procedures. In three out of nine cases in which the Schafer method (with back pressure and spring-off release) was used, the artificial respiration was found to be so inadequate that it was necessary to stop the procedure after several minutes because the condition of the subject was deteriorating. In all cases where the Schafer method was stopped, the push-pull method which immediately preceded it and the one which immediately followed it were found to be completely adequate and the patients remained in good condition throughout the 15-minute testing period.

Analysis of the blood specimens revealed that in all of the methods except the Schafer method the average values for oxygen saturation of the arterial blood were at near-normal levels. The mean value for the Schafer method was at an alarmingly low level.

Fatigue of the Operator: From a purely practical standpoint, it is important to know how fatiguing the various methods are. A selected group of average sized operators performed each of the methods on normal victims who were kept asleep with anaesthetic agents. They performed each method for 10 minutes and rested 1/2 hour between methods. During the tests the amount of work that the operators performed was measured on a metabolism spirometer by calculating the amount of oxygen they used during the application of each method. They also were asked how much fatigue they felt with the methods.

The results indicated that the Schafer method was always easiest and produced less fatigue. The hip-lift back-

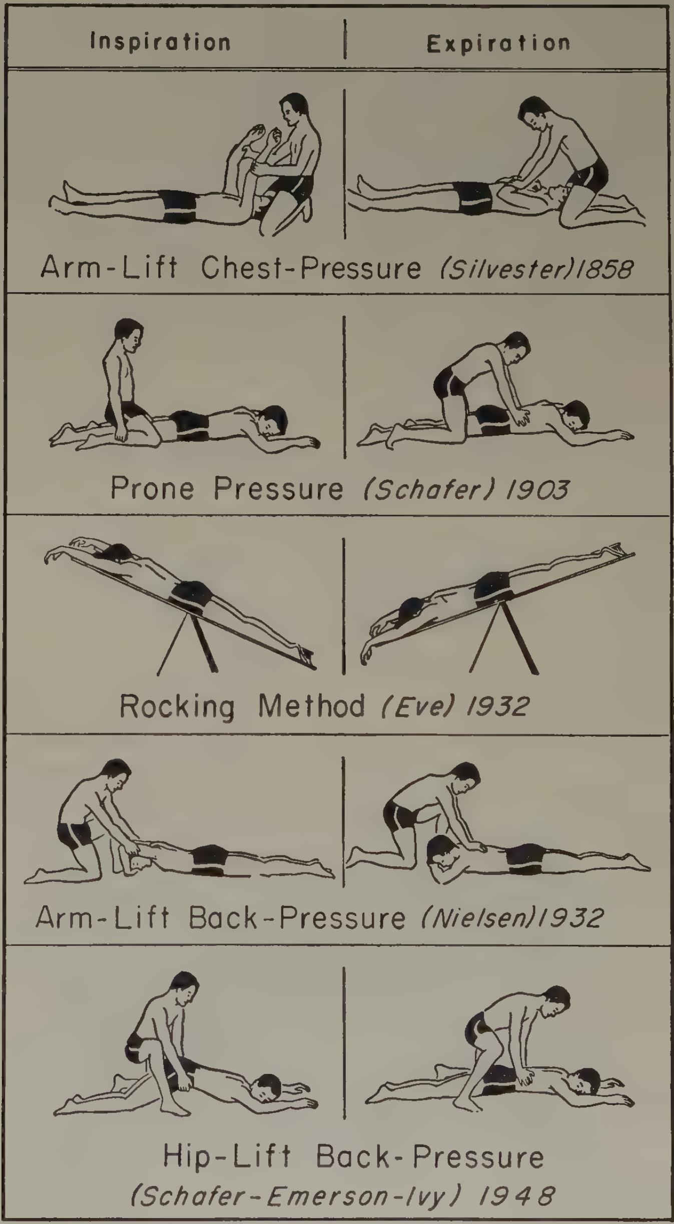
Inspiration
Expiration
Arm-Lift Chest-Pressure (Silvester) 1858
Prone Pressure (Schafer) 1903
Rocking Method (Eve) 1932
Arm-Lift Back-Pressure (Nielsen) 1932
Hip-Lift Back-Pressure
(Schafer-Emerson-Ivy) 1948

Figure 1. Methods of artificial respiration

pressure method resulted in the greatest expenditure of energy and caused the greatest fatigue; the hip-roll back-pressure method was the second most difficult. The arm-lift back-pressure method (Nielsen) and the arm-lift chest-pressure method (Silvester) occupied an intermediary position. Under the duress of the tests all of the operators, including two female medical students, were able to complete the 10-minute period with all of the methods.

Rate of Performance: Use of the pneumotachograph (sensitive air-flow meter) makes it possible to measure accurately the time required for each phase of the artificial respiration cycle. The push-pull methods each have four phases: (1) lift, or roll—active inspiration; (2) release—passive expiration; (3) press—active expiration; and (4) release—passive inspiration. Each of these phases was found to require an optimum duration of $1^{1}/_{2}$ seconds, or 6 seconds for the entire cycle. The passive, or release, phases are not important here and may be slightly accelerated, since the next phase is always an active one in the same direction of flow. Accordingly, a rate of 10 to 12 times per minute with each complete cycle occupying 5 to 6 seconds is found to be best.

Pedagogical and Performance Aspects: In order to appraise the teaching and performance factors concerned with the various methods, one thousand Naval Recruits and Waves were given lecture-demonstrations of the prone push-pull methods and then were required to perform each of the methods for 10 minutes. Despite the random pairing of operators and subjects, there were only a few cases where the operator could not complete the 10-minute performance period under the pressure of the experiment. The arm-lift back-pressure method was found to be the easiest of the prone push-pull methods to perform, and has been used successfully for 20 years in the Scandinavian countries; it was performed relatively more accurately than the hip methods after short periods of indoctrination. The hip-lift back-pressure method was the most difficult to perform but was applied with fewer errors than the hip-roll back-pressure method. This latter method was found to be more difficult to understand and apply correctly, and became awkward with prolonged use.

Both the hip-lift back-pressure and the hip-roll back-pressure methods were significantly easier to perform when an adjunct was used, such as a towel, belt, or rope, under the hips for lifting or rolling.

Trained personnel probably should know several of the manual resuscitation methods. The two preferred methods would be the arm-lift back-pressure and the hip-lift back-pressure. These would provide ready alternatives in cases of injury to or inability to manipulate either the arms or the legs. Since time is of prime importance, one of these methods must be started immediately when resuscitation is required.

Television in Medicine and Biology

V. K. ZWORYKIN
FELLOW AIEE

L. E. FLORY

Finding wide application in the classroom, the operating room, and the laboratory, television methods are quickly proving themselves as a valuable aid to medical science. The television microscope and other applications are described in this article.

TELEVISION HAS amply proved its value for the presentation of scientific progress to popular audiences. In the hands of men whose understanding of the subject is matched by their skill of interpretation, the science program is becoming a prized part of television entertainment and an effective means of spreading appreciation of the accomplishments and methods of the scientific worker. We need only mention The Johns Hopkins Science Review,[1] the science broadcasts of Dr. Roy K. Marshall, and Walter Kiernan's Kaleidoscope.

Our concern, however, is not so much with the popularizing function of television as with the use of television techniques for advancing and applying scientific knowledge in the fields of biology and medicine. We shall here define as television technique any technique which involves the electric transmission of images. This definition clearly excludes a wide range of by-products of television research which have come to play an important role in biological research and medical practice. Examples are the brightness intensifier,[2–4] which increases the effectiveness of X-ray fluoroscopy, and the scintillation counter,[5–7] useful in monitoring the administration of radioisotopes. A host of

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Full text of a conference paper recommended by the AIEE Committee on Electrical Techniques in Medicine and Biology; to be presented at the AIEE Conference on Electronic Instrumentation and Nucleonics in Medicine, New York, N. Y., January 7-8, 1951.

V. K. Zworykin and **L. E. Flory** are with the Radio Corporation of America Laboratories, Princeton, N. J.

The writers wish to express their appreciation for the contributions of J. M. Morgan, W. S. Pike, R. E. Shrader, J. M. Hillier, and E. G. Ramberg, all of RCA Laboratories. They also are indebted to Drs. W. Peacock and Leon Hellman of the Sloan-Kettering Institute for assistance in the program of evaluating the system for counting red blood cells. Special recognition is due to Dr. A. K. Parpart of Princeton University whose continuous work with the television microscope has been of inestimable value.

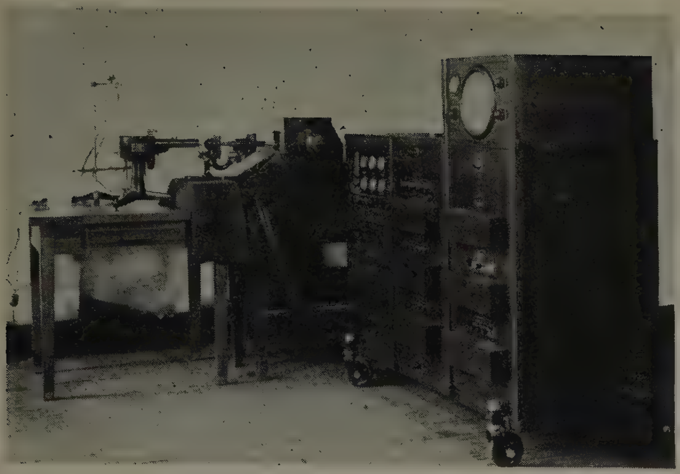


Figure 1. An early "electric microscope" using an iconoscope with a quartz window as pickup tube

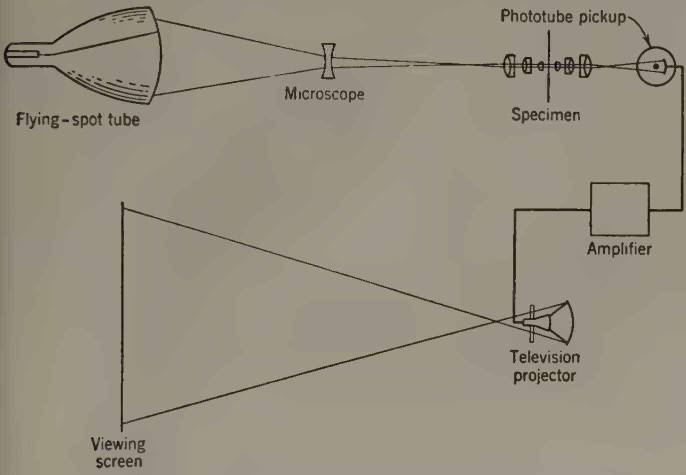


Figure 2. The relatively simple flying-spot microscope

other uses of the multiplier phototube might be added to the ever-increasing list.

THE TELEVISION MICROSCOPE

Even in the more restricted sense, however, television methods find wide application in research, advanced training, and medical diagnosis. The television microscope, in particular, promises to play an important role.

The basic idea of the television microscope is simple. It consists of a combination of an optical microscope and a television receiver or a multiplicity of receivers. The electrical link permits the regulation of location, size, brightness, and even contrast of the image independently of the limitations imposed by the illumination of the specimen. Thus a whole class of students is enabled to watch the same microspecimen on a large television screen while the instructor points out peculiarities or performs microdissections. Furthermore, the spectral range of sensitivity of the television microscope is not limited by the properties of the human eye; good results have been obtained with television pickup tubes operating in the far ultraviolet, even beyond the mercury resonance line (2,537 angstroms). Since the differential absorption of organic cell components is much greater in this part of the spectrum than in the visible, ultraviolet microscopy plays a particularly important role in cytology. The television microscope makes it possible to observe specimens in ultraviolet illumination of any selected wavelength with the same ease and continuity which characterizes observation in the visible. Employing the technique of differential absorption with the television microscope, Professor Parpart of Princeton University has been able to correct earlier misconceptions regarding the origin of observed variations in the appearance of red blood cells.[8]

The television microscope has, in fact, a longer history than is generally appreciated. An "electric microscope," employing an iconoscope with a quartz window as a pickup tube, was constructed in our laboratories as early as 1934.[9] The rather ponderous equipment is shown in Figure 1. By present-day standards, it left much to be desired in sensitivity and resolution. The employment of image tube converters to change an invisible microscope image into a visible one pursued similar ends but abandoned, for a time, the electric transmission feature which characterizes the television microscope.[10] At a much later date, the relatively simple flying-spot microscope sketched in Figure 2 was set up experimentally.[11] Here the raster formed on the screen of a flying-spot tube was imaged by an inverted microscope objective on the specimen and the transmitted light directed onto the cathode of a multiplier phototube. The phototube generated the picture signals for a projection kinescope scanned in synchronism with the flying-spot tube.

The flying-spot microscope is efficient in the utilization of the radiation impressed on the specimen—a consideration of importance, particularly, in the study of living tissues or microorganisms with ultraviolet illumination.[12] On the other hand, it is quite limited in the total illumination avail-

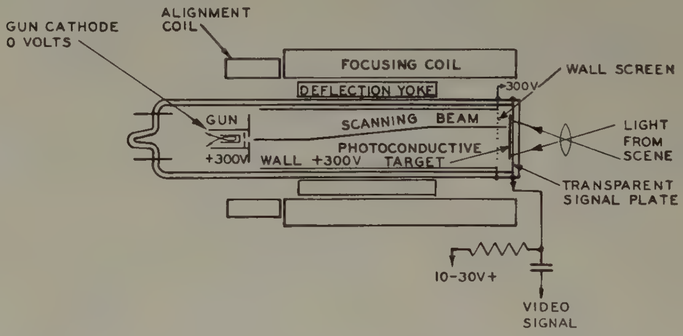


Figure 3. Diagram of the essential features of the Vidicon

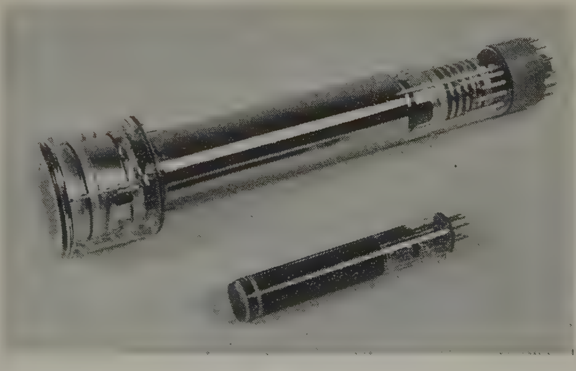


Figure 4. The Vidicon (bottom) compared with a conventional image orthicon

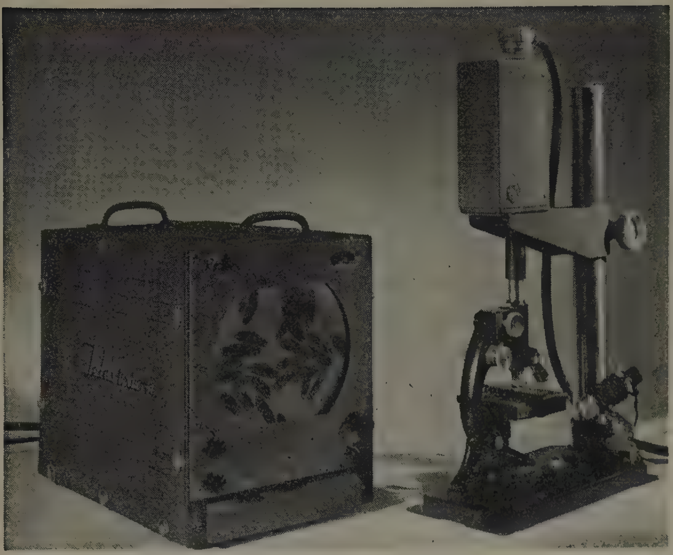


Figure 5. A television microscope unit with Vidicon camera mounted over a conventional microscope at right and the receiver unit at left

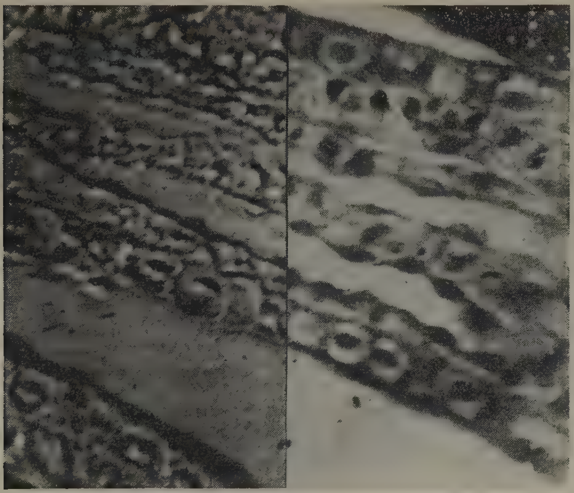


Figure 6. Television microscope image of a biological specimen illuminated at two different wavelengths to show how different contrasts may be achieved

able as well as in the spectral composition of the latter. This defect is remedied by the replacement of the flying-spot system by a storage pickup tube with characteristics which represent a great improvement over the early iconoscope. Such a tube is the Vidicon.[13] Here a high-resolution photoconductive target of extraordinarily high quantum efficiency scanned with low-velocity electrons leads to high sensitivity combined with compactness and simplicity of operation; see Figure 3. These properties fit the Vidicon ideally for television microscopy. The spectral response of the photoconductive target may be made to match, approximately, that of the human eye, extending throughout the visible spectrum. As an alternative, the sensitivity may peak in the blue and extend far into the ultraviolet.

The Vidicon itself is only 1 inch in diameter and some 6 inches in length; this is shown in Figure 4. Since the picture on the target is only about 1/2 inch in width, it can be employed conveniently with a standard microscope.

The camera designed for use with the Vidicon is about the size and shape of a 16-millimeter movie camera. It is mounted over the conventional microscope in such a position that the projected image falls on the photosensitive surface of the tube. The camera is cable-connected to a monitor and control unit. This unit is of about the size and complexity of a home television receiver. In fact, it resembles a receiver in many of its details. This control unit supplies all of the voltages and scanning signals necessary to operate the camera and, in addition, displays the television image on a viewing screen. At the control unit, the operator can control the brightness and contrast of the reproduced picture at will. The television microscope is shown in Figure 5.

The unique properties of electric amplifying circuits permit a narrow contrast range in the original specimen to be expanded to fill the entire contrast range of the television system. This provides a contrast enhancement over that present in the specimen viewed directly. This enhancement permits the practical use of magnifications in excess of those normally considered useful with the light microscope.

The ability of the Vidicon to respond to ultraviolet illumination permits unstained, or even living specimens in some cases, to be viewed directly with high contrast because of the high specific absorption of certain biological materials at different wavelengths. A good example of this is the high absorption of nucleic acid found in the nuclei of cells in the vicinity of 2,600 angstroms. This property is shown in Figure 6 which illustrates a television image of an unstained kidney section the left half of which is illuminated by light at 3,600 angstroms, while the right half is illuminated at 2,537 angstroms. The high absorption of the cell nuclei at the shorter wavelength is very apparent. A television microscope with reflective optics and a monochromator used with a mercury-arc source is shown in Figure 7.

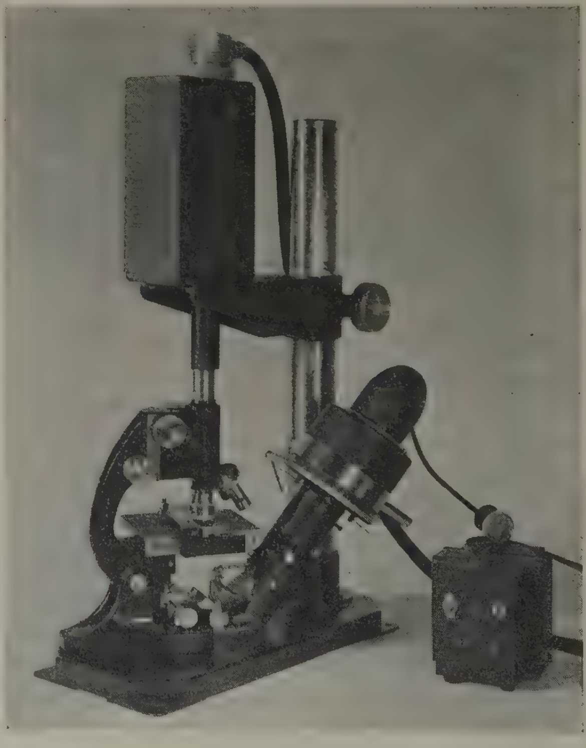


Figure 7. The television microscope with an ultraviolet light source

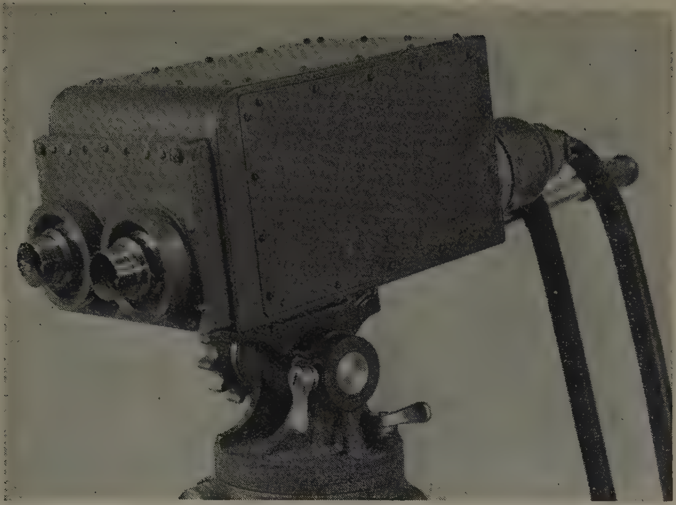


Figure 8. Stereoscopic Vidicon camera for 3-dimensional effect

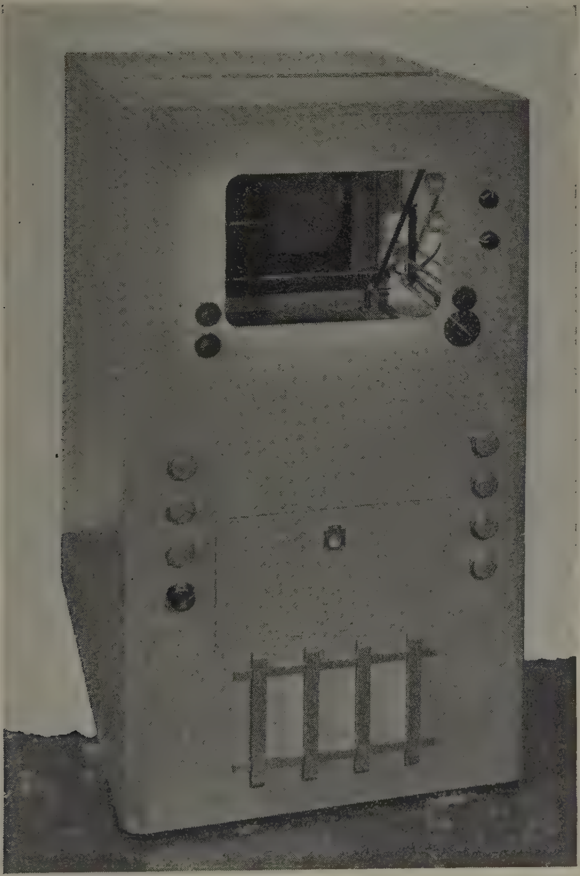


Figure 9. A stereo television receiver. The image must be viewed through Polaroid glasses

USES IN EDUCATION AND RESEARCH

Whereas the television microscope is thus pre-eminent in its potentialities for research and education in the fields of biology and medicine, the simple television camera joined by a closed link to a receiver or system of receivers has already demonstrated its value in medical education. Its usefulness in the demonstration of psychiatric techniques in interviews with patients, eliminating the disturbing effect of an audience, is obvious; so is its use for surveillance purposes in hospitals. It has achieved its greatest value, however, in the operating theater. With the camera mounted directly above the surgeon's work, students and guest physicians can witness every detail of the surgery without interfering in any way with the progress of the operation. The employment of color cameras and receivers enhances the instructiveness of the observed pictures.[14]

Of particular value is 3-dimensional observation, indicating the correct spatial relationship of the surgeon's tools and the parts upon which the operation is performed. For this purpose, a double Vidicon camera (Figure 8) is employed. The two images, formed on two separate kinescopes, are polarized in mutually perpendicular planes and superposed optically by a semireflecting mirror. Thus, when viewed through Polaroid spectacles, the receiver presents a view of the operation as seen from the vantage point of the two camera lenses, each eye seeing the image produced by one lens only. Such a stereo television receiver is shown in Figure 9. The use of the stereo camera in the operating room is shown in Figure 10.

The employment of television methods of a rudimentary type is gaining increased adherence in the study of heart and brain activity, as revealed by the space and time variation of skin potentials. The smallness of these variations precludes the generation of potential patterns with the degree of detail customary in television practice; furthermore, fine detail is not even desirable, since it would be indicative of local skin conditions rather than of the functioning of the organ in question, namely, the heart or brain. In any case, "area displays" of skin potentials, originally proposed by Dr. Douglas Goldman for the localization of brain tumors, have been found to yield information which goes well beyond the visualization of localized abnormalities. In particular, they reveal, apart from stationary variations, the presence and properties of traveling potential waves, which may eventually prove an aid in diagnosis.[15]

The systems employed for presenting the potential pattern differ in several details. Goldman and his associates at the Massachusetts Institute of Technology[16] (Figure 11)

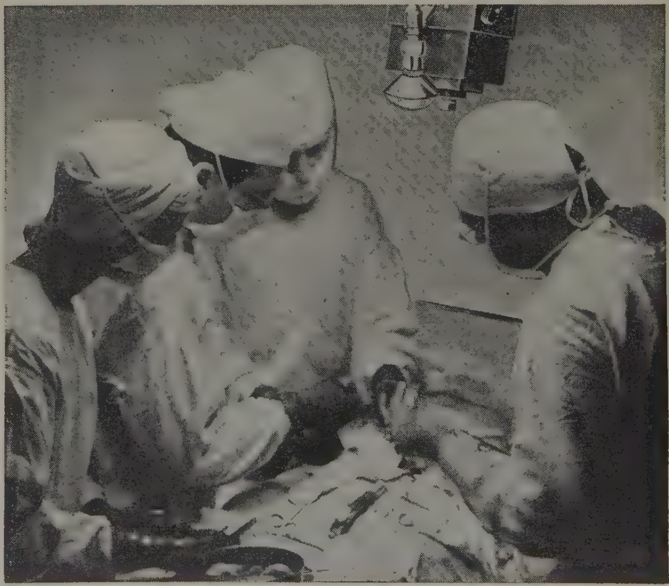


Figure 10. A stereoscopic television camera in use during a surgical operation

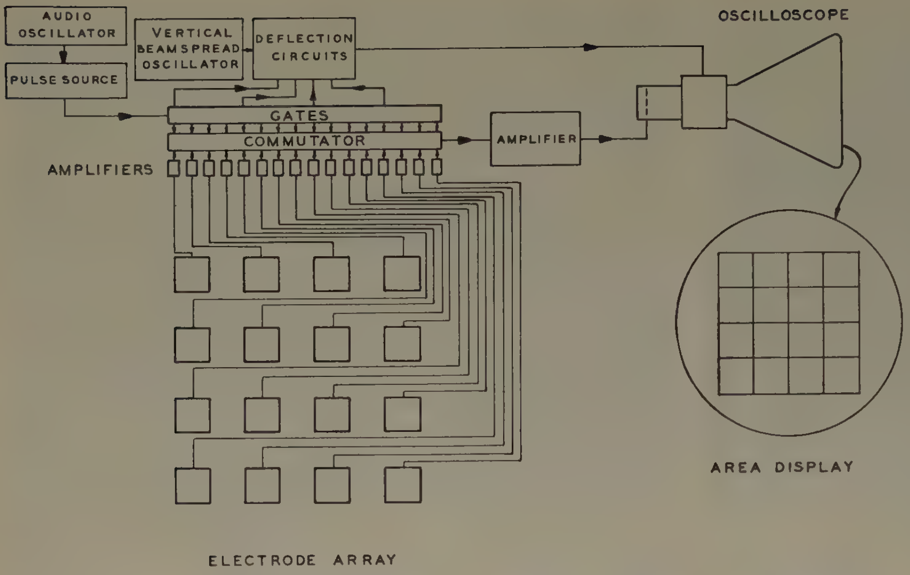


Figure 11. Principle of the area display method of S. Goldman and associates

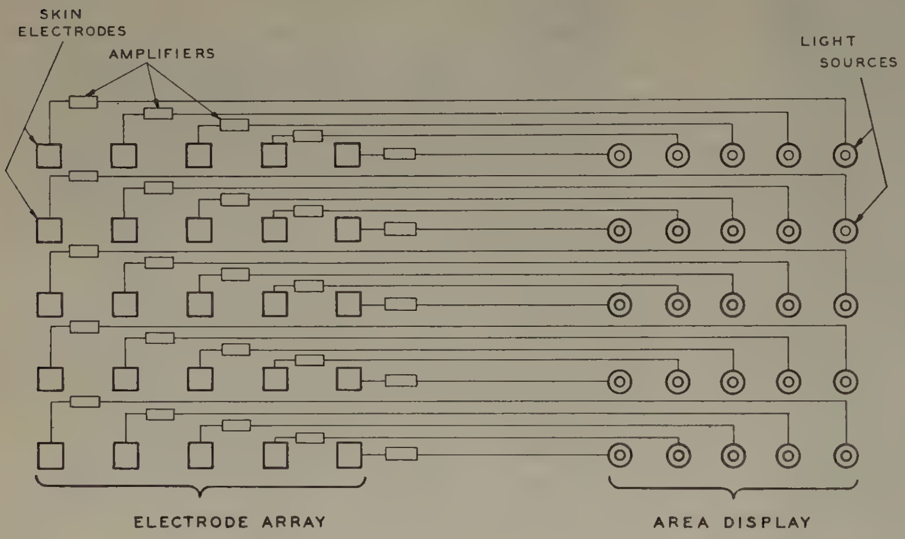


Figure 12. Principle of the area display method of J. C. Lilly

apply the amplified signals from an array of 16 electrodes on the chest of the patient through an electronic commutator to a cathode-ray tube. The potential pattern may either be observed on the face of the tube or be photographed by a motion-picture camera and be reprojected. Lilly,[17] at the Johnson Foundation of the University of Pennsylvania, utilizes instead the earliest technique proposed for television—originally described by G. R. Carey in 1875—of letting each electrode in the array (totaling 25) control the intensity or spot size of a circular light source in a geometrically similar array (Figure 12). The system of light sources then is photographed by a motion-picture camera at a high speed—namely, 64 or 128 pictures per second—and is reprojected at the lower speed of 16 pictures per second.

CELL COUNTING TECHNIQUES

A TELEVISION DEVICE of slightly later vintage—the Nipkow disk—finds employment in a system proposed by Mellors and Silver[18] of the Sloan-Kettering Institute for the early diagnosis of cancer. The diagnosis relies on the fact that the nuclei of cancer cells stained with certain basic fluorescent dyes, or fluorochromes, fluoresce more intensely than those of normal cells associated with them. In the system of Mellors and Silver, the specimen slide, with its stained cell suspension, is scanned by a flying spot of long-wave ultraviolet radiation (Figure 13). The spot size is of the same order as a cell nucleus in diameter, namely, 10 microns. It is formed by imaging, on a reduced scale, a Nipkow disk with 20 apertures on the specimen. Since the disk rotates at 30 revolutions per second and the scanning pattern consisting of 20 overlapping lines is 0.1 millimeter high and 0.25 millimeter wide, the scanning time for a single nucleus is about 66 microseconds. The mechanical stage is displaced automatically from one scanning area to the next so that, in due time, the entire field is explored.

The scanning is made sufficiently slow so that the signals produced by the fluorescent light from the cell nuclei, directed onto the cathode of a multiplier phototube, are not affected greatly by shot noise or amplifier noise. Electronic discriminators reject both excessively wide pulses originating from cell clusters, and the lower pulses generated by the nuclei of normal cells. The residual high and narrow pulses, such as are produced by cancer cell nuclei, are counted by an electronic counter.

This cancer cell counter solves a relatively complex particle-counting problem. A somewhat simpler problem, of great importance in clinical and preventive medicine, is the counting of red blood cells. Many efforts have been made to devise mechanical or electronic methods of carrying out the count, so as to increase its accuracy and to relieve technicians of a tedious and time-consuming task.

Earlier methods proposed for making blood counts employed a mechanical displacement of the microscope stage on which the counting chamber is mounted.[19,20] A light spot of the approximate dimensions of a single red cell is imaged on the counting chamber by a dark-field condenser, so that light reaches the signal-generating multiplier phototube only when a cell enters the light spot; see Figure 14. It is clear that the number of counts for a unit translation of the stage then will be determined by the sum of the spot diameter and the average diameter of the blood cells. To give a correct count, the diameter of the cells must be known. Since the cell diameter varies for different persons and for different states of health, this imposes a limit on the value of the method. The error may be reduced or eliminated by obtaining counts on dilute suspensions with two different large-diameter spots on the same specimen. The difference in the two counts then yields the number of particles within a strip of width equal to the difference in the two spot diameters.

This method is relatively indirect and is restricted to inconveniently dilute suspensions. By means of the television microscope, a sample of blood of proper dilution may be placed in a counting chamber of the same type as used for manual counting and an image of the field to be counted observed on the television screen. Since the image is reproduced by a continuous scanning action, the electric signal representing the field of blood cells consists of a series of electric impulses. Each impulse corresponds to the transit of the scanning beam across a cell. For fixed cell size, the measured pulse rate thus indicates the number of cells in a field of constant area. However, a large cell will register more counts than a small one, so that this simple method does not produce an accurate count in a practical case.

To obtain a figure representing the number of scanned cells independent of size, it is necessary to determine the average cell diameter and adjust the count obtained by the method just mentioned to correspond to this diameter.

In a practical counter for red cells, this has been done by comparing the length of the pulses produced by scanning the blood cells with a standard of pulse length which can be varied. Thus, the most prominent pulse length is determined by varying the standard until a maximum of coincidence is obtained. The reading of the pulse count then is adjusted automatically to read the true cell count.

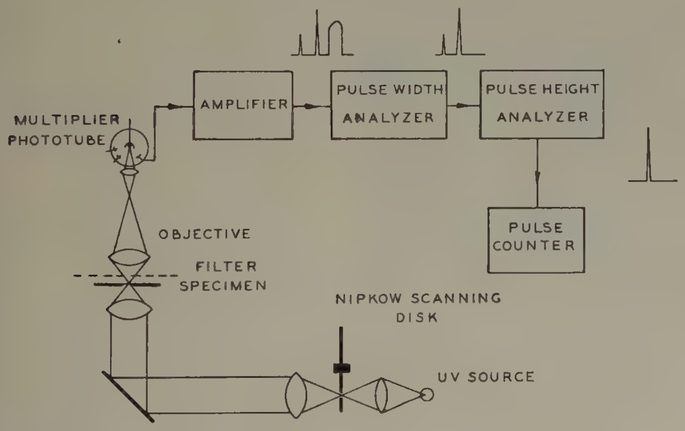


Figure 13. The Nipkow disk system for counting of cancer cells

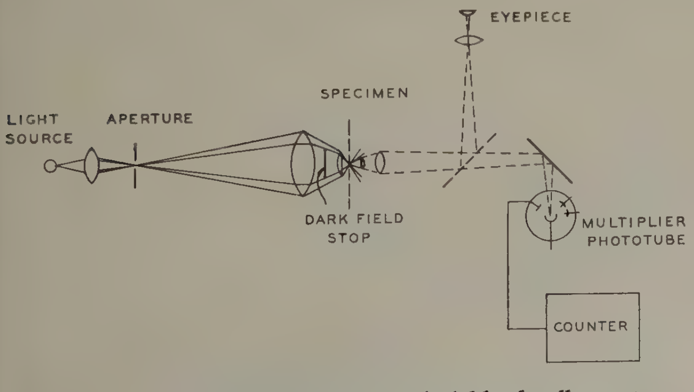


Figure 14. Principle of the mechanical blood cell counter

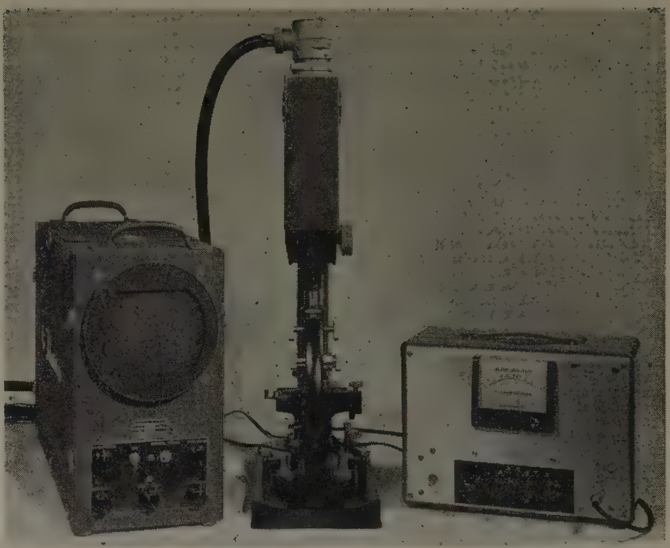


Figure 15. The television microscope adapted for counting blood cells

Such a counting device is shown in Figure 15. By means of this device, a count of red cells on a standard slide may be made in a few seconds with an accuracy equal to or better than the average manual count. In addition, the size compensation gives a measure of average cell diameter.

REFERENCES

1. Science via Television (book), **I. L. Poole.** Johns Hopkins Press, Baltimore, Md., 1950.

2. The Brightness Intensifier, **G. A. Morton, J. E. Ruedy, G. L. Krieger.** *RCA Review* (New York, N. Y.), volume 9, number 3, September 1948, pages 419–32.

3. Screen Intensification Systems and Their Limitations, **R. E. Sturm, R. H. Morgan.** *American Journal of Roentgenology and Radium Therapy* (Springfield, Ill.), volume 62, 1949, pages 617–34.

4. The Intensification of X-Ray Flourescent Images, **W. S. Lusby.** *Electrical Engineering*, volume 70, number 4, April 1951, pages 292–6.

5. **H. Kallmann.** *Natur und Technik*, July 1947.

6. The Photomultiplier Radiation Detector, **F. H. Marshall, J. W. Coltman, A. I. Bennett.** *Review of Scientific Instruments* (New York, N. Y.), volume 19, 1948, pages 744–70.

7. Photomultipliers for Scintillation Counting, **G. A. Morton.** *RCA Review* (New York, N. Y.), volume 10, number 4, December 1949, pages 525–53.

8. The Case against the Correlation of "Flicker" with Metabolism, **A. K. Parpart.** To be published in *Journal of Physiology of Journal of Cellular and Comparative Physiology.*

9. Electric Microscope, **V. K. Zworykin.** *1° Congresso Internazionale di Elettro-radiobiologia* (Venice, Italy), volume 1, 1934, pages 672–86.

10. Applied Electron Optics, **V. K. Zworykin, G. A. Morton.** *Journal*, Optical Society of America, volume 26, 1936, pages 181–9.

11. Photoelectricity and Its Application (book), **V. K. Zworykin, E. G. Ramberg** (quoting **R. C. Webb**). John Wiley and Sons, New York, N. Y., 1949, page 383.

12. A Flying-spot Microscope, **J. Z. Young, F. Roberts.** *Nature* (London, England), volume 167, February 10, 1951, page 231.

13. The Vidicon Photoconductive Camera Tube, **P. K. Weimer, S. V. Forgue, R. R. Goodrich.** *Electronics* (New York, N. Y.), volume 23, number 5, May 1950, pages 70–3.

14. 18-mc Telecolor for Surgical Training. *Electronics* (New York, N. Y.), volume 23, number 12, December 1950, page 182.

15. Traveling Waves in the Brain, **S. Goldman, W. F. Santelmann, Jr., W. E. Vivian, D. Goldman.** *Science* (New York, N. Y.), volume 109, 1949, page 524.

16. Electronic Mapping of the Activity of the Heart and the Brain, **S. Goldman, W. E. Vivian, C. K. Chien, H. N. Bowes.** *Science* (New York, N. Y.), volume 108, 1948, pages 720–3.

17. A 25-Channel Recorder for Mapping the Electric Potential Gradients of the Cerebral Cortex: Electro-iconograms, **J. C. Lilly.** *Electrical Engineering*, volume 69, number 1, January 1950, pages 68–9.

18. A Microfluorometric Scanner for the Differential Detection of Cells: Application to Exfoliate Cytology, **R. C. Mellors, R. Silver.** *Science* (New York, N. Y.), volume 114, October 5, 1951, pages 356–60.

19. Photoelectric Counting of Individual Microscopic Plant and Animal Cells, **C. Lagercrantz.** *Nature* (London, England), volume 161, 1948, page 25.

20. An Apparatus for Counting Small Particles in Random Distribution, with Special Reference to Red Blood-Corpuscles, **H. S. Wolff.** *Nature* (London, England), volume 165, 1950, page 967.

Steady-State Behavior of Carbon-Pile Regulators

D. G. SCORGIE
ASSOCIATE MEMBER AIEE

D. H. SCHAEFER
ASSOCIATE MEMBER AIEE

ATTEMPTS TO MEASURE the steady-state characteristics of carbon-pile voltage regulators have been made repeatedly and have ended in failure because, upon increasing the voltage applied to the operating coil, a point is reached where the carbon-pile resistance no longer can be controlled by normal adjustments. It is not sufficient to attribute this result to lack of sensitivity in controlling the voltage. Instead the measurements reported upon here indicate that there exists an operating voltage above which the carbon-pile resistance jumps discontinuously to a high value.

The measurements were made using an electronic circuit with feedback for controlling carbon-pile resistance directly. With its use, steady-state carbon-pile resistance versus operating-coil voltage hysteresis loops of an aircraft regulator have been measured. A set of curves has been obtained showing the effect of: 1. hysteresis, 2. heating of the carbon pile itself, and 3. ambient temperatures when the carbon pile is not itself a heat source. A theory of regulator operation was devised which explains adequately all the measurements.

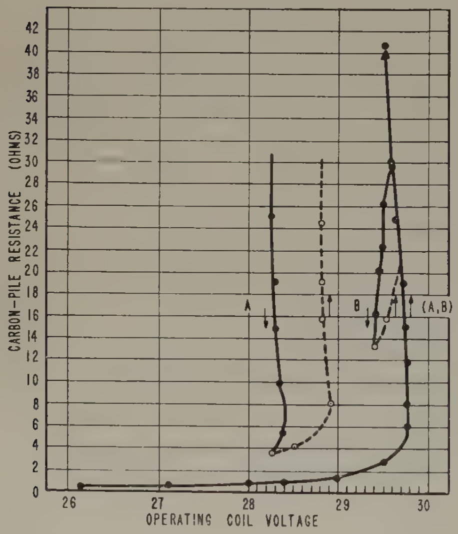


Figure 1. Minor hysteresis loops with low carbon-pile current (0.033 ampere). Regulator adjusted for 27.8 volts, no drop upon application of load

Figure 1 was obtained in such a manner that heating effects were negligible, that is, with carbon-pile dissipation less than 1 watt and the ambient temperature held constant. Curve 1A shows the loop traversed if the carbon pile is increased to infinite resistance, then decreased again. In curve 1B the resistance was increased only to 30 ohms before starting a minor hysteresis loop. The $1^1/_2$-volt spread for a given resistance is due to and explainable on the basis of magnetic hysteresis.

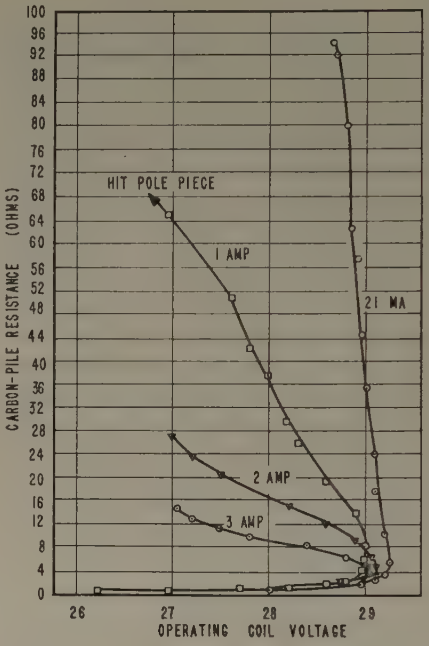


Figure 2. Ascending portions of loops with various pile currents. Regulator adjusted for 27.3-volt zero drop upon application of load. Operating coil resistance ≅25.9Ω

High-grade iron with extremely small hysteresis was used in this regulator. The motion of the armature, however, greatly alters the reluctance of the magnetic circuit, hence greatly accentuates the hysteresis effect. Hysteresis due to friction and "stiction" in the carbon pile can be shown to be negligible on the scale of these curves and, in fact, tends slightly to move the descending portion of the curve to the right. The net effect of some hysteresis is beneficial because it exerts a stabilizing effect for small disturbances. It has been shown theoretically[1] that without hysteresis or some comparable nonlinearity perfect regulation is impossible, for instability must necessarily result. Hysteresis allows perfect regulation or even a voltage rise with large load disturbances in a stable system.

Figure 2 shows the effect of carbon-pile heating. Here the measurements were taken at carbon-pile power dissipations on the same order of magnitude as occur in normal operation. The data for this figure were taken with the ambient temperature controlled so as to hold the operating coil resistance constant. Therefore these curves are explainable on the basis of temperature changes of the carbon pile. Only the ascending portions of the loops are shown in Figure 2. Data also were obtained showing the effect of ambient temperature alone. On the regulator-tested temperature compensators in the operating coil housing balanced out the effect of two-thirds of the operating-coil resistance change.

REFERENCE

1. Transient Analysis of Voltage-Regulated Aircraft D-C System, **D. G. Scorgie.** AIEE *Transactions*, volume 69, part II, 1950, pages 1318–23.

Digest of paper **51-295,** "Steady-State Characteristics of Carbon-Pile Voltage Regulators," recommended by the AIEE Committee on Air Transportation and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions,* volume 70, 1951.

D. G. Scorgie and **D. H. Schaefer** are both with the Naval Research Laboratory, Washington, D. C.

Benjamin Franklin's Kite Experiment and Other Electrical Discoveries

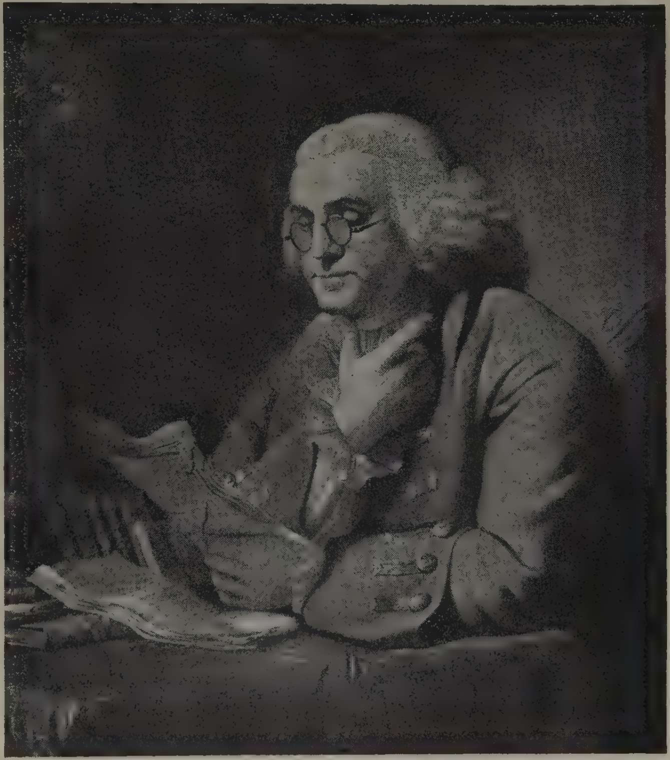
JANET BERMINGHAM
EDITORIAL STAFF

THE YEAR 1952 is the 200th anniversary of the flying of Benjamin Franklin's historic kite which drew electric charges from the atmosphere and proved the electrical nature of lightning. At that time Benjamin Franklin was 46 years old and already had attained fame as a printer, author, inventor, publisher, educator, scientist, philosopher, and patriot. His accomplishments are so varied that to comprehend all of them and their resulting effects on the history of civilization presents problems in time, understanding, and breadth of knowledge. That this is true is in itself a great tribute to Franklin.

Studies in electricity greatly interested Franklin, the scientist, and his famous kite experiment has merited him the widest public acclaim. Franklin was not the first to conduct this experiment; it had been carried out successfully by several Europeans who had read of Franklin's theories concerning the nature of lightning and electricity, but he performed his work not knowing of their successes.[1]

A description[2] by the late Howard McClenahan of Franklin's kite experiment and the study which preceded it shows very well how he applied his powers of mind and reasoning to answering the problems of the universe.

"He began his electrical studies with the investigation of the discharging power of points. He took a metal ball four inches in diameter and placed it on the mouth of a clean dry glass bottle. This was his insulated conductor. By a silk thread he suspended a cork ball perhaps one quarter of an inch in diameter, so that it could rest against the side of the metal ball. When the metal ball was electrified, the cork ball was vigorously repelled, to a distance of four or five inches. Franklin found that, when in this state, if a long, sharply pointed bodkin, at a distance of six or eight inches be pointed at the metal ball, the repulsion upon the cork ball at once vanishes and the cork falls back to the metal. If the bodkin be held by an insulating handle of sealing wax, it loses the power of discharging the metal ball, but regains this power immediately when the ball is grounded by touching.



Courtesy of the American Philosophical Society

This portrait of Benjamin Franklin painted by Charles Willson Peale is known as the "Thumb Portrait." The original was painted by David Martin to the order of Robert Alexander of Edinburgh to commemorate services given him by Franklin, who so approved of the picture as a correct likeness that he had Martin paint him a replica which he retained during his lifetime and in his will bequeathed to the State of Pennsylvania

"Franklin then attached a needle, or bodkin, with a sharp point, to the metal ball and found at once that no repelling force could be exerted upon the cork ball because, as he said, no charge could be kept upon the ball to which the needle was attached. The charge which would otherwise have accumulated on the metal ball was 'thrown off' by the point. He repeated his experiments in the dark and found that the needle was often surrounded by a glow of light.

"Franklin at once turned his talent for usefulness upon this study. Other experiments which cannot be described, for want of space, showed many evidences of similarities between the electric sparks which he could produce and the lightning discharge of nature. He surmised that the two actions had the same origin—electricity—and differed only in the magnitudes of the quantities involved. Recalling the action of the pointed needle in making it impossible to keep a charge on the metal ball, he asked if, similarly, charges of electricity on the earth or the clouds

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Acknowledgement is gratefully made to J. Henry Smythe, Jr., for suggesting this article and for his valuable assistance in preparing it.

could not be drawn off harmlessly by a pointed rod placed on a height and conductingly connected to the earth? This was the origin of his famous kite experiment. He meant to erect what we should call a lightning rod on a steeple which was to be built. Growing weary of the delay, he took a kite with him to higher ground and as a thunder storm approached, sent up his kite. When the silk cord by which it was held became wet from rain, he could, and did, draw electric sparks from the brass key which was tied near the lower end of the cord."

After the kite experiment had shown Franklin that lightning and electricity were the same, he performed further experiments with the lightning rod. In his yard he erected a permanent rod which was connected to a set of bells which sounded whenever the rod became electrically charged. The members of his household would run to the rod and draw off carefully into Leyden jars, or condensers, some of the charge on the rod. Franklin subsequently studied the charges which were drawn off.

FRANKLIN'S THEORY OF ELECTRICITY

His observations of the nature of electricity and electrical actions are commented on further[3] in detail by Dr. McClenahan.

"Franklin regarded electricity as a 'subtile substance' which permeated all matter. Matter was a 'spunge' for electricity, behaving toward that fluid as the ordinary sponge does towards water. When matter possessed just the normal amount of the electric fluid, it showed no signs of charge; it was surcharged. If more were added to it, it was said to be positively charged, while if any electricity were taken from the body, it was negatively charged, or had a negative charge. There was but one kind of electricity, according to Franklin's notion. . . . A positive charge was only an excess of the electric fluid while negative charge was a deficiency, or lack, of the fluid. In any electrical transaction, as in the rubbing of glass with silk, or sealing wax with wool, some electricity passes from one body, leaving it negatively charged, to the other body, making it positively charged. The total amount of electricity remains unchanged; it is merely differently distributed. Franklin believed that the charge, whatever its sign, was distributed through the whole volume of the body, conductor or non-conductor, which bore it. He seemed to have no idea of anything like the concentration of the charge upon the surface only of the body which actually occurs. There were, naturally, inaccuracies in Franklin's theory and in his ideas, yet they were the forerunners of modern theories of electricity and the foundation upon which the modern structure rests."

The late Professor William Duane[4] credits Franklin with giving the world the best theory of electricity. Modern science has adopted his early conclusions after nearly two centuries of further investigation and controversy. Franklin believed that electricity consists of very minute particles, so small that they can pass between the atoms of ordinary matter, and that they repel each other and are attracted by the atoms of ordinary matter. Within the last 50 or 60 years scientists have been able to isolate and study in detail these atoms of electricity, which are now called electrons. It is from these earlier studies that today's around-the-world radio communication is made possible as well as all the other utilizations of the modern electron tube.

In working with electricity, Franklin became the first man to discharge an explosive located at a distance by an electric current sent over a wire.

MEDICAL APPLICATIONS OF ELECTRICITY

Probably because of his unfailing desire to apply knowledge for the benefit of mankind, Franklin tried to find some application of his electrical theories in the field of medicine or in treatments for illness. After applying shocks to patients and trying to electrify doses of medicine without any visible success, he came to the conclusion that electrical treatments did not result in curative action for his patients. In a letter[5] written to John Pringle in 1757 Franklin himself tells of his experiments in electrotherapy.

"In compliance with your request, I send you the following account of what I can at present recollect relating to the effects of electricity in paralytic cases which have fallen under my observation.

"Some years since, when the newspapers made mention of great cures performed in Italy and Germany by means of electricity, a number of paralytics were brought to me from different parts of Pennsylvania and the neighbouring provinces, to be electrized, which I did for them at their request. My method was to place the patient first in a chair, on an electric stool, and draw a number of large strong sparks from all parts of the affected limb or side. Then I fully charged two six-gallon glass jars, each of which had about three square feet of surface coated; and I sent the united shock of these through the affected limb or limbs, repeating the stroke commonly three times each day. The first thing observed was an immediate greater sensible warmth in the lame limbs that had received the stroke than in the others; and the next morning the patients usually related that they had in the night felt a pricking sensation in the flesh of the paralytic limbs; and would sometimes show a number of red spots which they supposed were occasioned by those prickings. The limbs, too, were found more capable of voluntary motion, and seemed to receive strength. A man, for instance, who could not the first day lift the lame hand from off his knee, would the next day raise it four or five inches, the third day higher; and on the fifth day was able, but with a feeble languid motion, to take off his hat. These appearances gave great spirits to the patients, and made them hope a perfect cure; but I do not remember that I ever saw any amendment after the fifth day; which the patients perceiving, and finding the shocks pretty severe, they became discouraged, went home, and in a short time relapsed; so that I never knew any advantage from electricity in palsies that was permanent. And how far the apparent temporary advantage might arise from the exercise in the patients' journey, and coming daily to my house, or from the spirits given by the hope of success, enabling them to exert more strength in moving their limbs, I will not pretend to say."

Franklin himself received several shocks while experimenting with electricity. It is very fortunate for this country that he received no permanent injury as a result of his scientific work for his great contributions to this country's political history were still to be made. He describes in another letter[6] a shock received while treating a patient.

"I had a paralytic patient in my chamber, whose friends brought him to receive some electric shocks. I made them join hands so as to receive the shock at the same time, and I charged two large jars to give it. By the number of those people I was obliged to quit my usual standing and placed myself inadvertently under an iron hook which hung from the ceiling down to within two inches of my head and communicated by a wire with the outside of the jars. I attempted to discharge them, and in fact did so; but I did not perceive it, though the charge went through me and not through the persons I intended it for. I neither saw the flash, heard the report, nor felt the stroke. When my senses returned, I found myself on the floor. I got up, not knowing how that had happened. I then again attempted to discharge the jars; but one of the company told me they were already discharged, which I could not at first believe, but on trial found it true. They told me they had not felt it, but they saw I was knocked down by it, which had greatly surprised them. On recollecting myself, and examining my situation, I found the case clear. A small swelling rose on the top of my head, which continued sore for some days; but I do not remember any other effect good or bad. . . . "

From the New York Public Library Collection

This 19th century wood engraving by Alexander Anderson (American) shows Benjamin Franklin with his son conducting his famous kite experiment

To review all Franklin's achievements in the field of electricity in detail is beyond the limits of time and space, the purpose here being merely to bring to mind again the importance of Benjamin Franklin's scientific contributions to the modern age.

To appreciate the magnitude of Franklin's accomplishments in science, it is necessary to picture the physical conditions under which he lived, and the absence of all scholars who could refute his errors or stimulate his scientific thinking. Dr. McClenahan shows this clearly when he describes[7] Franklin without the proper apparatus, without books of reference, without scientific journals. He was a pioneer in a scientific wilderness, just as others were in the primitive Colonies.

Franklin was America's first natural philosopher and must be ranked with her greatest. The author of "Poor Richard" was no metaphysical speculator, but must be classified as the original American pragmatist.

It was the opinion of the late Michael I. Pupin[8] that Franklin was " . . . the leader of a new scientific movement which was destined to reveal to man a new physical reality, the reality of electricity in motion. . . ." Furthermore, Benjamin Franklin had a deep sense of service to his fellow citizens which inspired him to start the movement for higher scientific activity in the American Colonies culminating in the birth of the American Philosophical Society and the University of Pennsylvania.

McClenahan observes[9] that Franklin was " . . . of an extremely philosophical cast of mind. He had a fearless love of truth and a basic honesty, which manifested themselves in the seemingly pointless repetitions of his experiments, made again and again and again, in order to care only for the result and to have no pride of authorship. He was painstakingly careful and willing always, even eager, to correct his mistakes. He was a great scientist, by whatever standards we test him, and he gave to the world of science knowledge of lasting importance and novelty. In any list of the original scientists of the world, Franklin's name must always appear. For fundamental importance, for daring imagination, and for successful endeavor, he must always be ranked with the leaders. . . . "

REFERENCES

1. The Amazing Benjamin Franklin (book), compiled and edited by **J. Henry Smythe, Jr.** Frederick A. Stokes Company, New York, N. Y., 1929, page 164. (Out of print.)
2. Ibid, pages 165–6.
3. Ibid, pages 170–1.
4. Ibid, page 259.
5. Benjamin Franklin's Autobiographical Writings (book), selected and edited by **Carl Van Doren.** The Viking Press, New York, N. Y., 1945, pages 73–4.
6. Ibid, page 73.
7. Smythe, op. cit., page 172.
8. Ibid, pages 174, 176.
9. Ibid, pages 172–3.

A Magnetic Fluid Dynamometer

D. W. BREDE
ASSOCIATE MEMBER AIEE

SINCE THE ANNOUNCEMENT of the magnetic fluid by J. Rabinow[1] in 1948, several manufacturers have been producing magnetic fluid clutches for use primarily in servomechanisms. Though some manufacturers also have produced designs for breaking service, the author knows of no instance where the magnetic fluid has been used for absorption-dynamometer applications. The smoothness of control and the possibility of simple water cooling make this use very attractive.

Proration of a clutch design suggested by Rabinow[1] was used as a starting point in the design of the dynamometer, the main differences being size and provision for water cooling. The dynamometer so designed measured 7 inches in length by 8 inches in diameter and was calculated to absorb 10 horsepower at 400 rpm with a cooling-water temperature rise of about 10 degrees centigrade.

To test the dynamometer it was driven by a 10-horsepower d-c machine with a rated speed range of from 600 rpm to 1,800 rpm. Simultaneous measurements then were made of torque and exciting current with a fixed flow of cooling water. Temperature rise also was measured at several points in the dynamometer for different loadings.

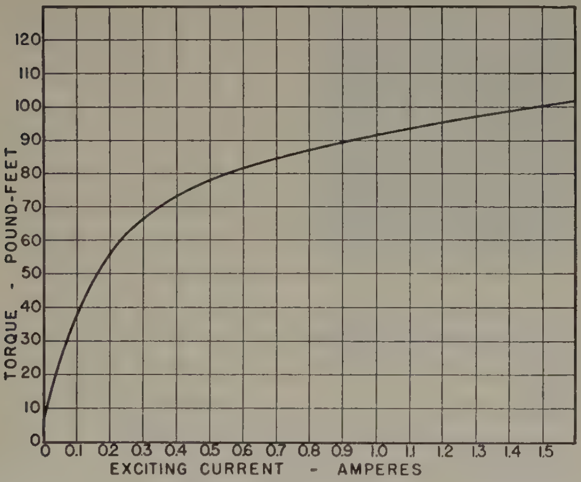

Figure 1. The torque versus exciting-current characteristic of the dynamometer

The torque versus exciting-current characteristic is shown in Figure 1. This characteristic was found to be independent of speed from 400 rpm to 1,200 rpm and decreased slightly above 1,200 rpm. The power absorbed was calculated from the torque and speed measurements and was found to vary from 8 horsepower at 400 rpm to 22 horsepower at 1,800 rpm. These values of power absorbed were limited by the characteristics of the d-c machine used and the allowable temperature rise in the dynamometer. When the dynamometer was absorbing 10 horsepower the cooling-water temperature rise was about 15 degrees centigrade and the internal temperature rise in the dynamometer was about 75 degrees centigrade.

Of the several mixtures of magnetic fluid tested in the dynamometer, a mixture of seven parts by weight of iron (carbonyl E) and one part by weight of oil (silicone oil, 20 centistokes viscosity) was found to give the largest controllable torque with a minimum of residual torque. The residual torque is caused by the viscosity of the fluid mixture with zero exciting current. The magnetic fluid was observed to expand with rise in temperature and to have a considerable abrasive effect.

Because of the abrasive effect of the magnetic fluid and the increase in pressure in the fluid caused by the thermal expansion, the seals were subjected to difficult operating conditions. To operate the dynamometer at all special seals had to be designed to minimize the abrasive effect and provision made to allow for the increase in volume to minimize the pressure problem.

In addition to the tests described, measurements were made of the flux density distribution in the gaps of the dynamometer. From these measurements and the torque versus exciting-current characteristic, the torque versus average flux-density characteristic was determined. This relation is very interesting in that the torque is a linear function of the flux density whereas in a machine like the eddy-current brake the torque is a function of the square of the flux density. A proportionality constant was evaluated from this relation as 0.24 pound per kiloline for the dynamometer described using the magnetic fluid mixture noted previously.

The magnetic fluid dynamometer provides an absorption dynamometer giving good control and torque characteristics. Once the dynamometer has been calibrated for its torque versus exciting-current characteristic, the torque can be determined easily by measurement of the exciting current and reference to the calibration curve, or the ammeter used may be calibrated directly in values of torque. In addition, the range where the torque is a linear function of the exciting current may be extended by proper design of the dynamometer. A mechanical power output meter then can be made by combining the exciting current of a dynamometer so designed with the linear output of a conventional electric tachometer in an electrodynamometer-type instrument.

Digest of paper 51-307, recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

D. W. Brede is with the University of California, Berkeley, Calif.

REFERENCE

1. Magnetic Fluid Clutch, **J. Rabinow.** *Technical News Bulletin,* United States Bureau of Standards, Washington, D. C., volume 32, 1948, pages 54–60.

The Use of Selenium Rectifiers in Self-Saturating Magnetic Amplifiers

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J. R. CONRATH
ASSOCIATE MEMBER AIEE

The particular characteristics of self-saturating magnetic amplifiers must be considered when selecting selenium rectifiers for their circuits. The effects of forward voltage drop, leakage, and capacitance are discussed, as is the selection of a rectifier stack for an amplifier.

RATINGS OF selenium rectifiers for use with self-saturating magnetic amplifiers may differ from those in other applications for two important reasons. It is necessary to rate the rectifiers conservatively so that their life and stability will be consistent with those of the other magnetic amplifier components. The reactors, whose construction is similar to that of transformers, may be expected to have an almost unlimited maintenance-free life if not abused. Selenium cells often are used at a much lower reverse voltage in magnetic amplifiers than in most other applications. The reverse current usually is limited to such a small value that it has almost no effect on the temperature rise of the rectifier. Even small changes in rectifier characteristics may have considerable effect on the gain of sensitive magnetic amplifiers. In balanced or push-pull amplifiers, rectifier instability is the largest factor contributing to drift or noise output.

Rectifiers in self-saturating magnetic amplifiers, unlike those in other applications, experience a variety of current and voltage waveforms, depending on the magnitude of the control signal applied to the amplifier. To demonstrate this, consider the half-wave magnetic amplifier circuit shown in Figure 1. This is composed of a single reactor having an output winding and a control winding, a half-wave rectifier stack, a load resistor, and a source of a-c voltage. This circuit is taken as an example because of its simplicity; only an elementary explanation of its operation is offered here so that the rectifier requirements can be understood. This half-wave circuit is not generally useful because a high impedance must be used in the control circuit to limit the induced current. However, practical amplifier circuits consist of two or more of these units with their control coils so connected that no fundamental frequency voltage appears at the control circuit terminals. During the first part of the cycle substantially all the supply voltage is absorbed by the change of flux linkages in the reactor; after the core saturates the greater part of the supply voltage appears across the load for the remainder of the positive alternation. The voltage absorbed by the reactor is proportional to the change in flux and therefore depends on the flux at the start of the positive alternation. This initial value of flux is adjusted by a direct current in the control winding. During the negative alternation the change of flux linkages absorbs the same portion of the supply voltage as before; the rectifier must withstand the supply voltage for the remainder of the cycle.

Sketches of the waveforms in a half-wave magnetic amplifier are shown in Figure 2. For full output, saturation occurs early in the cycle; the forward current and rectifier reverse voltage approach sinusoidal form. For relatively small output, saturation occurs late in the cycle and the waveforms of the quantities mentioned become nearly triangular. For cutoff, saturation does not occur, and current and rectifier reverse voltage are both small. It is evident, then, that the rectifier is subjected to maximum reverse voltage as well as maximum forward current for the condition of full output. Unless a definite duty cycle can be anticipated, it is necessary to design the rectifier for continuous full output.

FORWARD VOLTAGE DROP AND REVERSE CURRENT

THE EFFECT OF rectifier forward voltage drop in magnetic amplifiers is readily apparent. The load voltage is

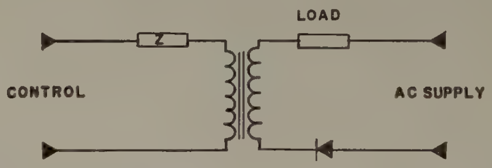

Figure 1. A simple half-wave magnetic amplifier circuit

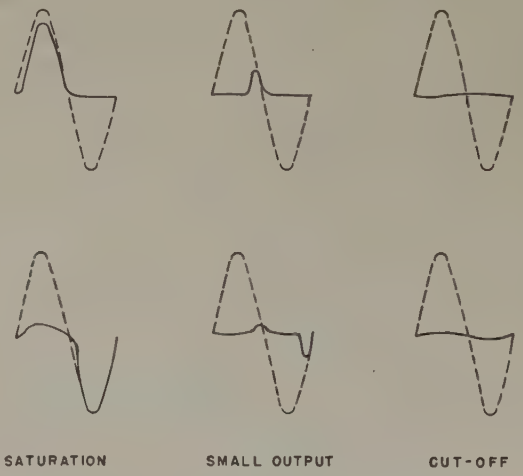

Figure 2. Rectifier current (top row) and voltage (bottom row) waveforms in a self-saturating magnetic amplifier

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Essentially full text of a conference paper presented at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951.

J. R. Conrath is with Vickers Electric Division, Vickers, Inc., St. Louis, Mo.

the supply voltage minus the voltage absorbed by the reactor and the rectifier forward voltage drop. Any change in this forward voltage drop means an equal and opposite change in load voltage. Aging of the rectifiers will produce a loss of output just as in simple rectifier circuits.

The effect of rectifier reverse current is a decrease of sensitivity of the amplifier. For this reason the rectifiers usually are operated at a low reverse voltage. This is particularly necessary in amplifiers employing gapless high permeability cores for maximum sensitivity.

It was indicated in the foregoing explanation that the load current of a magnetic amplifier is controlled by adjusting the flux density at the start of the positive alternation of supply voltage. In flowing through the output winding, reverse current produces a magnetomotive force which reduces the flux in the reactor at the start of the positive alternation of supply voltage; the reactor then can absorb a greater voltage and so the load voltage is less than it would have been had there been no reverse current. Figure 3 shows the effect of reverse current on the control characteristic of a typical magnetic amplifier. To simulate the effect of rectifier leakage without changing the forward voltage appreciably, the rectifier was shunted with a suitable resistor. It will be noted that neither the saturation value of output current nor the control signal required to produce cutoff has been changed, but the change in control signal for a given change in output is increased. Figure 4 shows the control signal for full output of this amplifier as a function of rectifier reverse current. If this curve is extrapolated the intercept on the vertical axis may be thought of as the control signal necessary to saturate the core with a perfect rectifier; in any actual case an additional (proportional) component of control signal is necessary to overcome the effect of reverse current.

It might be thought that the demagnetizing effect of reverse current could be represented by a magnetomotive force computed by multiplying the reverse current by the number of turns in the output winding. Measurements taken on a number of amplifiers using various circuits and types of cores indicate that a component of control signal two or three times this computed amount must be used to overcome the effect of reverse current. This can be explained by the fact that the reverse current flows for less than half of the cycle; hence its average value during this part of the cycle is more than twice its average taken on the basis of a full cycle. Furthermore, it happens that the reverse current flows only during that part of the cycle when such a current is effective in changing the output of the amplifier; that is, during the unsaturated period just before the beginning of the positive alternation of supply voltage.

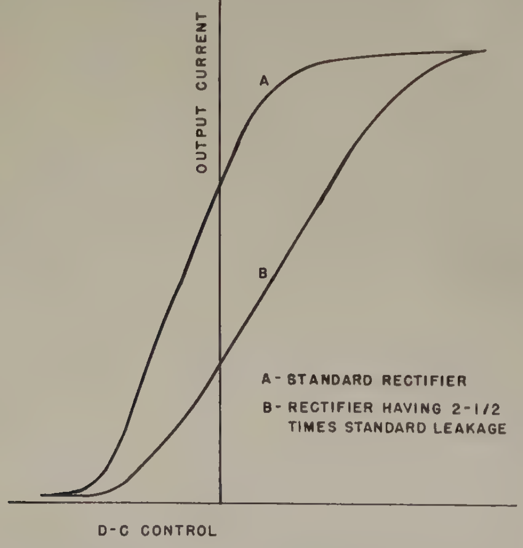

Figure 3. Control characteristics for two values of rectifier leakage

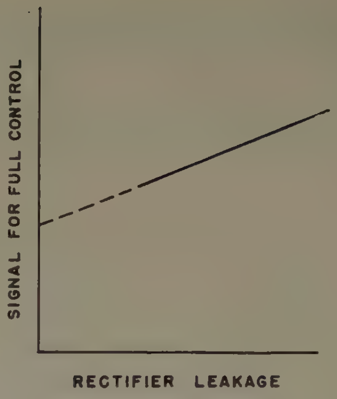

Figure 4. Effect of rectifier leakage on signal required for full control

In sorting cells for magnetic amplifier use it is important to measure the reverse current at the voltage at which the cells will be used in the amplifier. Cells which appear to be matched at the voltage at which they would be used in power rectifiers may vary widely in reverse current when measured at lower voltage.

In addition to the resistive, or leakage, component of reverse current there also exists a component due to the capacitance of the rectifier. In sensitive amplifiers the effect of rectifier capacitance is appreciable with a 60-cycle power supply; with a 400-cycle power supply its effect is sometimes greater than that of leakage. If magnetic amplifiers are to be used as audio amplifiers, a much higher supply frequency must be used. Selenium rectifiers may be unsuitable for such amplifiers because of their capacitance; probably germanium rectifiers will be most practical.

To construct a sketch of the reverse current waveform of a half-wave selenium rectifier operated at low reverse voltage, consider the waveform of the rectifier voltage as indicated in Figure 5*A*. The capacitive component of current, which is always proportional to the rate of change of rectifier voltage, is indicated in Figure 5*B*. The resistive component of current is as shown in Figure 5*C*. The total rectifier current is the sum of these two components and its waveform is shown in Figure 5*D*. It will be noted that two peaks of reverse current occur, one corresponding to capacitance, the other to leakage.

The existence of waveforms such as these may be demonstrated by the circuit arrangement of Figure 6. The current divides between the parallel rectifiers of this circuit so that only the reverse current flows through the resistance to which the cathode-ray oscilloscope is connected. With a suitably low supply voltage the pattern observed will be similar to the reverse current portion of the waveform of Figure 5*D*. The relative heights of the peaks of reverse current will depend on supply voltage and frequency and on the leakage and capacitance of the rectifier.

A simple measurement of the effective capacitance of a rectifier cell under conditions approximating those in a magnetic amplifier may be made by connecting the cell in the circuit of Figure 6. The height of the reverse current peak corresponding to the capacitance is observed. Then a calibrated variable capacitor is shunted across the rectifier cell and so adjusted that the height of this current peak is doubled. Since the height of this peak is proportional to the total capacitance, it is evident that the capacitance of the rectifier will be equal to the value to which the shunt capacitor had to be adjusted to double the height of the original peak. Measurements of this type on a number of selenium cells indicate a capacitance of about 0.02 microfarad per square centimeter of rectifying area.

SELECTION OF A RECTIFIER STACK

The reverse voltage ratings used for rectifiers in self-saturating magnetic amplifiers depend on the type of core material and on the core construction used in the reactors. Low-level amplifier stages generally are designed for maximum sensitivity; they employ gapless cores of high permeability magnetic material. Such amplifiers require a particularly small rectifier reverse current; perhaps one- or two-tenths of one per cent of the forward current at full output. In power stages sensitivity is not as important; more consideration is given to economy. Such stages may employ cores having an air gap and less expensive magnetic materials. Consequently the rectifier reverse current may be considerably greater before its demagnetizing effect becomes comparable with the magnetomotive force required to saturate the core. Evidently then, the rectifiers in low-level magnetic amplifier stages should be operated at a lower voltage per cell than those in power stages. In amplifiers which feature gapless cores of high permeability material a typical value would be 10 volts per cell; in amplifiers which employ cut Hipersil cores a typical value would be 20 volts per cell.

The selection of a rectifier stack for a self-saturating magnetic amplifier is accomplished readily. The current rating of the reactors (which usually is limited by temperature rise) determines the rectifier cell size. This also fixes the allowable value of reverse current if a specified ratio of reverse current to forward current is to be maintained. This value of reverse current then determines the reverse voltage per cell and hence the number of cells in series which must be used in the amplifier.

If a current ratio of 0.001 is maintained with a typical cell used at its ordinary forward current rating, the reverse voltage might be limited to 10 volts. If now a smaller rectifier cell size is used and if additional cooling is somehow provided so that the forward current rating remains the same, then obviously the current density will be increased. This means that the same ratio of reverse to forward current will be maintained with a higher reverse voltage per cell. Furthermore, the ratio of reverse to forward voltage will be improved; the forward voltage will be increased by the greater current density but to a considerably smaller extent than the reverse voltage. This is true, of course, only for reverse voltages less than that corresponding to the bend in the reverse current characteristic. It was found that with the selenium cells tested the maximum ratio of reverse to forward voltage (for a current ratio of 0.001) occurs at a current density about three times that usually used for magnetic amplifier rectifiers. Consequently if a stack is to withstand a given reverse voltage with the specified percentage of reverse current, the forward voltage will be minimum for this current density. The reverse voltage per cell corresponding to this condition is approximately 18 volts.

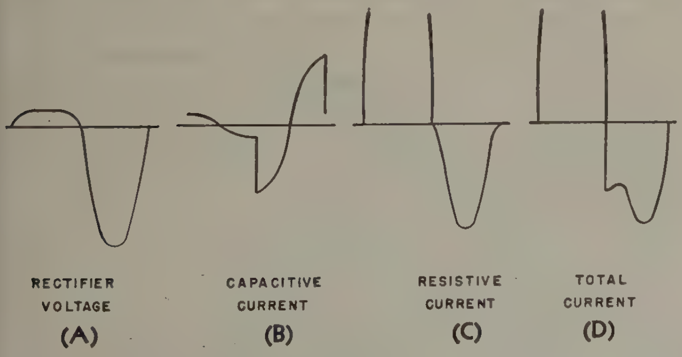

Figure 5. Waveforms in a half-wave rectifier circuit with resistive load and low supply voltage. (Forward current peaks not shown)

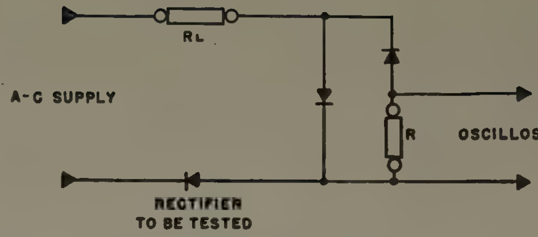

Figure 6. Circuit for displaying rectifier reverse current waveforms

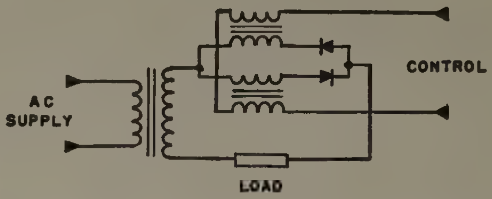

Figure 7. A doubler magnetic amplifier circuit

The frequency of the supply voltage influences the size of the rectifiers in magnetic amplifiers. The voltage rating of a reactor increases directly with the frequency; the number of cells in series in the rectifier would also have to increase proportionately if the same ratio of reverse to forward current were to be maintained. Since the rectifiers in 60-cycle amplifiers are comparable in size to the reactors, it can be seen that those in 400-cycle amplifiers have a tendency to be unduly large. For this reason, the rectifiers in 400-cycle amplifiers may be operated at a higher voltage per cell, thus increasing the reverse current and the control signal required for a given reactor. However, since this decreases the number of cells in series in the rectifier, it also decreases the power loss in the rectifier and so increases the power output of the amplifier. Furthermore, since the power output increases with frequency, the power gain of an amplifier is greater with a 400-cycle supply than with 60 cycles, even though the control requirement is considerably higher.

In the half-wave amplifier circuit previously discussed the maximum reverse voltage which the rectifier must withstand is the supply voltage; it is not appreciably affected by the value of the load resistance. In practical amplifiers the circuits comprise two or more half-wave amplifiers working into a common load resistance. The rectifier reverse voltage then is a combination of the supply voltage and the load voltage. For example, Figure 7 shows the "doubler" circuit, which provides a-c output in the load. It is evident that in this circuit the reverse voltage on the rectifiers is the supply voltage minus the load voltage. For low values of load resistance the reverse voltage approaches the supply voltage; for large values of load resistance it approaches zero. Figure 8 shows the full-wave circuit which produces d-c output in the load. Here the rectifier reverse voltage is the supply voltage (measured from midtap to line) plus the load voltage. In this circuit the reverse voltage approaches the supply voltage for small load resistances; it approaches twice that value for large load resistances. Various other magnetic amplifier connections exist, single-phase and 3-phase. In each case the circuit must be examined to determine the effect of the load on rectifier reverse voltage.

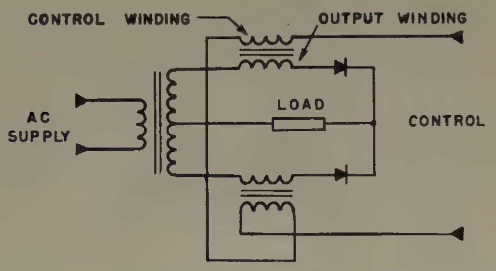

Figure 8. A full-wave magnetic amplifier circuit

AMBIENT TEMPERATURE

IN SELF-SATURATING magnetic amplifiers the effect of ambient temperature on the rectifiers may be a more serious limitation than in most other rectifier applications. The reverse current increases for both high and very low temperatures and therefore tends in either case to reduce the gain. In the forward direction the negative temperature coefficient of the rectifier tends to be offset by the positive coefficient of resistance of the reactor windings. When the reverse voltage per cell is held to a relatively low value (as it must be in amplifiers designed for maximum gain), it has been found possible to obtain practical operating characteristics over a wide range of temperature. No loss of sensitivity was observed in amplifiers tested at −40 degrees centigrade. However, there may be a noticeable change at elevated ambient temperatures; a decrease of as much as 50 per cent in the slope of the control characteristic has been observed in amplifiers operating with normal rectifiers at +70 degrees centigrade. When ambient temperatures above 35 degrees centigrade are anticipated special consideration should be given to the rectifiers not only with respect to leakage but also to forward current derating.

High-Voltage A-C Motor Controllers

G. W. HEUMANN
MEMBER AIEE

Some trends in the present-day design and use of a-c motor controllers for use on systems with line voltage from 601 to 5,000 volts are discussed, and some of the essential differences between controllers using air-break contacts and oil-immersed contacts are pointed out.

THE AIEE, AMERICAN Standards Association, and National Electrical Manufacturers Association (NEMA) standards limit the scope of the term "industrial control" to operating voltages of 5,000 volts or less. Thus, when considering high-voltage a-c motor controllers, it generally is understood that the term means controllers for motors connected to power systems with a line voltage between 601 and 5,000 volts. Practically all high-voltage a-c motors are connected to power systems having a nominal rating of 2,400 or 4,160 volts.

Choice of high-voltage versus low-voltage controllers is not left to the control engineer. Choice of motor voltages in an industrial plant is determined by considerations of power system economy, and once motor voltage has been chosen, the controller builder must be prepared to design controllers to handle any type and size of motor.

High-voltage controllers must perform the same duties as low-voltage controllers, namely, start, stop, and protect the motor. Expressed differently, they must make, carry, and break the normal starting and running motor current at all times. An interrupting ability of 10 times rated motor current would permit a controller to interrupt the stalled-rotor current of a squirrel-cage induction motor. Such a controller, designated under NEMA Standards for Industrial Control[1] as "class-*A*" controller, would be

Full text of a conference paper recommended by the AIEE Committee on Industrial Control and presented at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951.

G. W. Heumann is with the General Electric Company, Schenectady, N. Y.

capable of interrupting any operating overload on the motor. Many high-voltage controllers have been installed in former years which do not have an interrupting rating beyond 10 times rated motor current.

Short circuits may occur on any power system, and they must be considered in the design of the electric equipment. The magnitude of the short-circuit current which may flow through a controller bears no relation to the size of the motor connected to the controller, but it is determined by the characteristics of the power system and the total connected rotating machinery which may contribute to the fault current.

In former years, it was considered good practice to protect the branch circuits in which the controllers are located by backup circuit breakers in the substation or in the power station. Such circuit breakers were often oil circuit breakers requiring approximately 8 cycles to clear the fault. Such backup protection was entirely adequate as long as system capacities were small and the available energy flowing through the controller during fault conditions was at a sufficiently low level as not to cause serious damage to the controller.

Today, because of increased power demands and greater interconnection between systems, the capacity of industrial power systems has grown to such a size that short-circuit currents are so large that serious damage would result in many cases if class-*A* controllers were installed with backup protection only, since slow-acting backup protection would permit a destructive amount of short-circuit energy to flow through the controller. Today's trend in the industry is to recognize the necessity of designing high-voltage controllers with high interrupting capacity so that the controller itself interrupts faults between controller and motor, without damage to controller and branch circuit. The day may not be far away when class-*A* controllers will no longer be recognized in industry standards as being suitable for use on high-voltage systems.

High-voltage controllers with high interrupting rating are designated as class-*E* controllers under NEMA standards. Depending on the means employed for interrupting short-circuit power, two principal types are recognized.

Class-*E1* controllers employ the main power contacts of the controller for both starting and stopping the motor and interrupting short circuits. Circuit breakers have been employed in class-*E1* controllers for starting the motor and interrupting short circuits. However, since circuit breakers are not designed inherently for frequent operation, their use as motor starters is limited. Most class-*E1* controllers which are on the market today employ contactors for starting and stopping the motor, and for interrupting short circuits. Within the generally accepted scope for industrial control equipment, class-*E1* controllers are available with interrupting ratings up to 50,000 kva. Class-*E2* controllers employ the main power contacts of the controller for starting and stopping the motor, and fuses for interrupting short circuits. Since the main power contacts usually have to interrupt no more than the ordinary starting currents and operating overloads of the motor, contactors equivalent to class *A*, having a comparatively low interrupting ability, may be used as part of class-*E2* controllers. The fuses, which assume the duty of interrupting short circuits, may be power fuses requiring approximately 1 cycle to clear a fault, or they may be current-limiting fuses which interrupt current flow before the initial current peak has been reached during the first half-cycle after the incidence of the fault. Class-*E2* controllers are available with interrupting ratings up to 150,000 kva at 2,400 volts and 250,000 kva at 4,160 volts.

Under certain high-impedance fault conditions, the controller overload relay may trip before the fuse interrupts the fault. Proper correlation between contactor interruption, due to overload relay tripping, and fuse interruption, is necessary. Likewise, the design of the contactor must allow for the let-through fault current which the contactor has to carry before the fuse clears the fault.

BASIS OF INTERRUPTING RATING

Shown in Figure 1 is a simplified power diagram of a faulted motor controller. To calculate the interrupting duty of a controller connected to a system rated 5,000 volts or less, it is customary to neglect the generators, step-up transformers, transmission lines, and contributions to the fault current of synchronous and induction motors. An infinite bus is assumed ahead of the step-down transformers, and the short-circuit power flowing into the fault is determined largely by the transformer and feeder impedance. Faults are most likely to occur in conduits, and they hardly ever occur inside the controller. The worst fault location would be at the controller load terminals. Since the impedance of the controller, which would tend to reduce the fault current, is a variable, depending on controller size and make, controller selection is based on the short-circuit current which would flow if the controller were short-circuited by a zero-impedance fault at its line terminals. The short-circuit current thus calculated is the "available" short-circuit current at the point of controller installation. Because of the simplifying assumptions entering into the calculation, the short-circuit current actually flowing into the fault will be rather somewhat smaller than the calculated value, and the previously described simplified method of calculation obtains satisfactory results as long as the contribution of synchronous and induction motors to the fault current does not exceed the effect due to the neglect of controller and fault impedances and the assumption of an infinite bus on the high side of the transformer.

The calculated short-circuit current is a symmetrical current, representing the rms value of a current wave as shown in Figure 2*A*. Actually, the short-

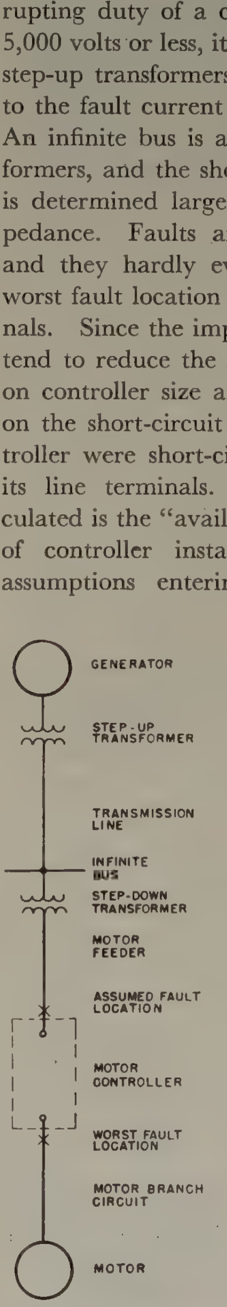

Figure 1. Simplified diagram of faulted motor power circuit

circuit current may be "offset" by a d-c component, as in Figure 2*B*, the magnitude of which depends on the instant the short circuit occurs, and the decrement of which depends on the X/R ratio of the power circuit. When circuit breakers or power fuses are employed to clear the short circuit, which permit short-circuit current to flow for a full cycle or more, the current actually interrupted is the symmetrical short-circuit current plus the d-c component. It is customary to rate circuit breakers and power fuses in terms of actually interrupted short-circuit power. They are applied on the basis of a calculated symmetrical short-circuit current multiplied by a factor which considers the d-c component, and which depends on the system characteristics and the required interrupting time.

When current-limiting fuses are used on class-*E2* controllers, the rating basis just given loses its significance since the fuse does not pass the peak of the short-circuit current which would flow with no fuse in the circuit; see Figure 3. Because of the difference in rate of rise of current, an unsymmetrical short-circuit current often is interrupted at a lower instantaneous value than a corresponding symmetrical current. There would be no sense in rating current-limiting fuses in terms of actually interrupted short-circuit current, hence current-limiting fuses are rated in terms of symmetrical available short-circuit kilovolt-amperes which they are capable of interrupting.

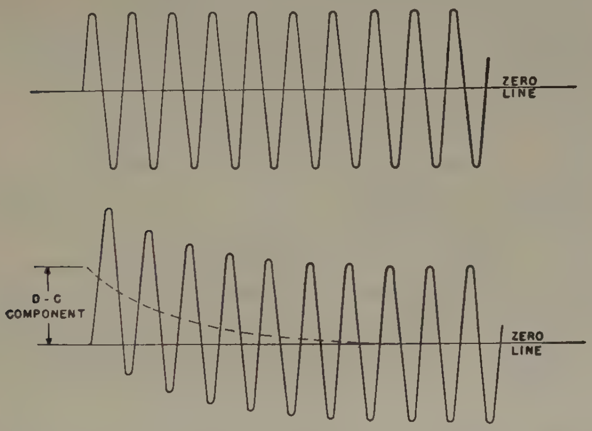

Figure 2 (A). Symmetrical short-circuit current (top); and 2 (B) asymmetrical short-circuit current (bottom)

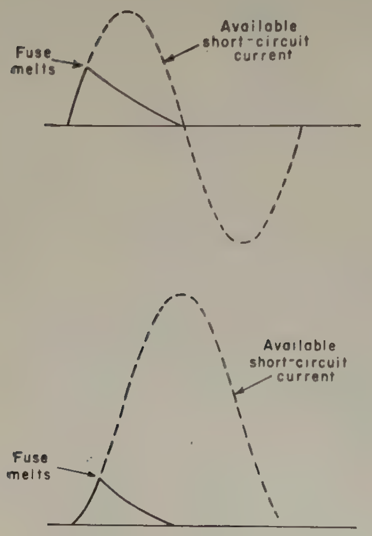

Figure 3. Current interruption by a current-limiting high-voltage fuse

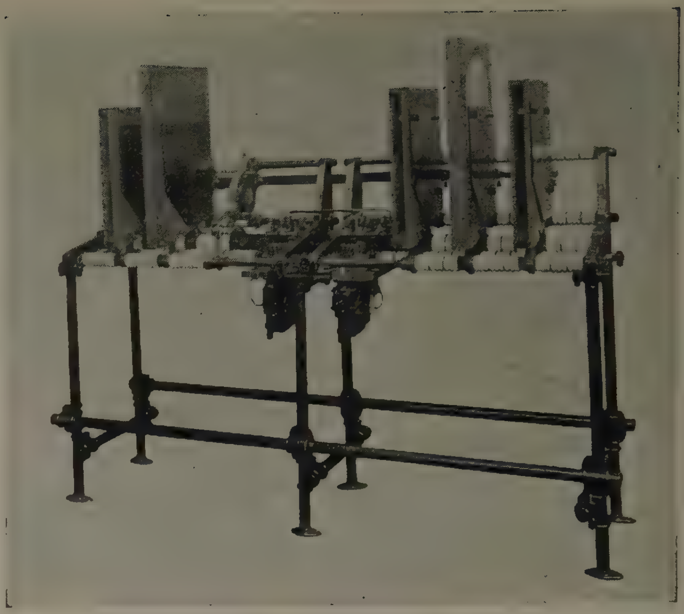

Figure 4. High-voltage air-break reversing contactor for mine hoist service, circa 1920

A user who has to install a high-voltage controller would have to know first the available symmetrical short-circuit kilovolt-amperes of his power system at the point of controller installation. To place all class-*E* controllers on a common basis of application, the controller manufacturers rate class-*E1* and -*E2* controllers in terms of available symmetrical short-circuit kilovolt-amperes. It is then up to the controller designer to factor-in the interrupting time of the circuit-interrupting device he chooses, and he must allow for the short-circuit energy which may flow through the controller. To the user, the job of controller selection thereby is simplified, and a class-*E1* or -*E2* controller of a certain interrupting rating would perform satisfactorily at a given location.

OIL-IMMERSED AND AIR-BREAK CONTACTORS

CLASS-*E* CONTROLLERS utilizing contactors with high interrupting rating have been built successfully with either oil-immersed or air-break contactors. In an oil-immersed contactor, all arcing parts are enclosed in an oil tank and they are below the oil level. The contacts in many cases are not equipped with blowout and arc chutes, and the oil is relied on to quench the power arcs. The most important advantage of oil-immersed contactors is the protection afforded by the oil against explosion when control equipment is installed in a hazardous atmosphere.

Several disadvantages, however, should be considered when selecting oil-immersed versus air-break contactors. The oil tank requires a certain amount of maintenance since a leaky oil tank is a definite fire hazard. Any insulating oil will carbonize and sludge in time; therefore contactor parts must be cleaned and oil renewed at regular intervals. Experience has revealed that contacts arcing under oil have shorter life than contacts arcing in air. Thus, oil-immersed contactors are under a handicap with respect to contact life when the motor is started and stopped frequently.

Air-break contactors must be equipped with blowouts and arc chutes. Any possible fire hazard due to the presence of oil is eliminated, maintenance is simplified, and contact life is increased. Hence, air-break contactors for many years have been preferred on controllers used for frequent starting and stopping of the motor.

In the past, high-voltage air-break contactors were much larger than oil-immersed contactors of equal rating. Figure 4 shows a reversing air-break contactor, circa 1920, illustrating a design which had not changed materially for many years. The contactor is sprawly, and when switching motor currents under heavy load conditions, sheets of flame and hot gases, and often parts of the arc, were emitted from the arc chutes. Thus, large spacings between phases and between the contacts and structural parts were required. While such spacings were tolerable on single-motor installations, for instance, in the hoist house of a mine, they became a serious disadvantage when a number of high-voltage motor controllers had to be assembled into a line-up of enclosed control panels.

During the past few years significant advances have been made in the design of air-break high-voltage contactors, based on intense research and development work on high-voltage arc interruption. Shown in Figure 5 is a 1950 vintage nonreversing air-break contactor capable of controlling a motor of twice the size of the one controlled by the 1920 contactor of Figure 4. The new contactor is much more compact, and over-all dimensions are greatly reduced. The most significant feature of modern high-voltage air-break contactors is the design of their arc chutes and associated parts. Current interruption takes place entirely within the arc chute with little, if any, flame emitted. Thus, it became possible to reduce spacings between phases, and between the contactor and adjacent parts.

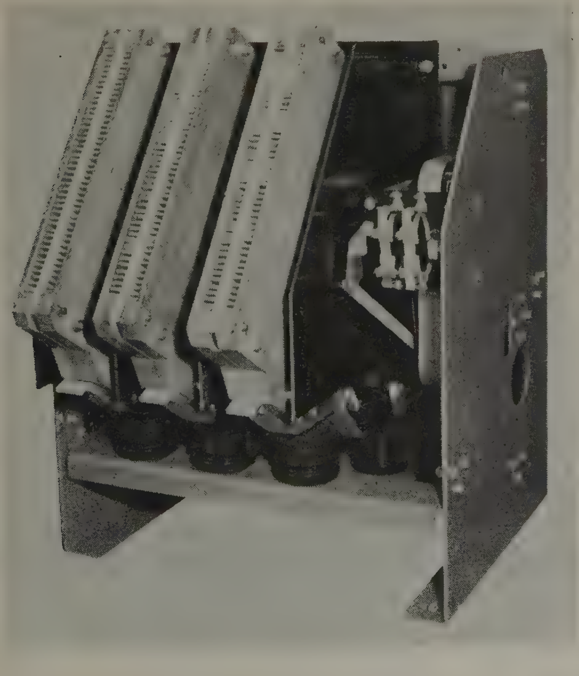

Figure 5. High-voltage air-break contactor, 1950 design

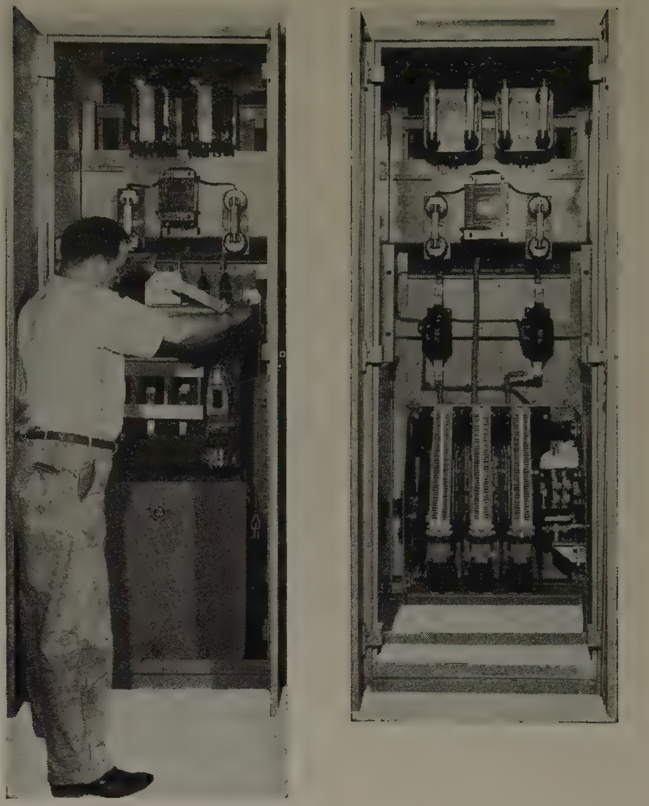

Figure 6. Class-E2 high-voltage starters. With oil-immersed line contactor (left); and air-break line contactors (right)

This evolution in design permits air-break contactors to be used in enclosures having dimensions comparable to those required for oil-immersed contactors of equivalent rating. Figure 6 illustrates two class-*E2* controllers, one with air-break and the other with oil-immersed contactor, both mounted in enclosures of the same size. Thus, it has become practicable to use air-break contactors in enclosed panel line-ups. With the reduction in over-all space requirements, we may expect greatly increased usage of air-break contactors for controlling general-purpose high-voltage motors, in addition to continuing their old use for heavy-duty material handling and similar equipment involving frequent intermittent service.

In conclusion, the following statements concerning present-day trends in the design of high-voltage a-c motor controllers appear to be in order.

1. Because of greatly increased capacity of industrial power systems, users as well as manufacturers have become conscious of the necessity of specifying high-interrupting rating for high-voltage motor controllers.
2. Because of simplifications in the selection and application of motor controllers, manufacturers commonly base controller ratings on symmetrical short-circuit kilovolt-amperes available at point of controller installation.
3. Because of reduction in space required by recent designs of high-voltage air-break contactors, their increased use in controller line-ups may be expected.

REFERENCE

1. Standards for Industrial Control. National Electrical Manufacturers Association (New York, N. Y.), publication *IC1-1949, article IC1-2.8*, 1949.

Relation of Traveling Waves to Fault Locators

L. J. LEWIS
MEMBER AIEE

THE RESPONSE of a fault locator utilizing traveling waves to measure distance to a fault depends not only on the design of the fault locator but also on the characteristics of the waves themselves. A mathematical analysis of a 3-phase system shows that because of losses and coupling between lines, two surge components are produced which travel at different speeds. The slow wave is equivalent to a current flow in the three wires in parallel, with a ground return; the fast wave is equivalent to current flow confined to the line conductors.

For fault-locator applications, three problems exist involving traveling-wave characteristics: the separation of the surge into components, determination of the nature of propagation, and calculation of the effect of discontinuities.

The resolution of a surge into voltage and current components is a problem of determining 12 coefficients from a set of six equations. For this determination, three initial conditions are needed, together with a set of relations between components. The nature of the components is dependent on the type of surge. Equations have been derived to determine the separate wave components for a variety of possible initial conditions.

The difference in attenuation of the slow and fast components is of major importance. Experience shows that the slow wave is greatly attenuated in comparison with the fast wave. As a result, in cases involving considerable distance of travel, the slow wave can be disregarded. Major attention therefore is directed to the fast wave, which travels very nearly at the velocity of light.

Calculation of the effect of a fault or other discontinuity to a traveling surge can be made by a method employing superposition; see Figure 1. In this example, the incident waves reaching the fault consist only of the fast waves, produced when a voltage is applied to a single conductor and voltages are induced on the other two phases. It is to be noted that the sum of the voltages and the sum of the currents are zero, this being a characteristic of the fast waves. At a 2-line-to-ground fault, two of the line voltages become zero; also no current change occurs on the third conductor. The reflection components may be simulated by applying two generators having voltages equal and opposite to those of the incident waves. Superposition results in zero voltage on the grounded conductors, the condition imposed by the fault.

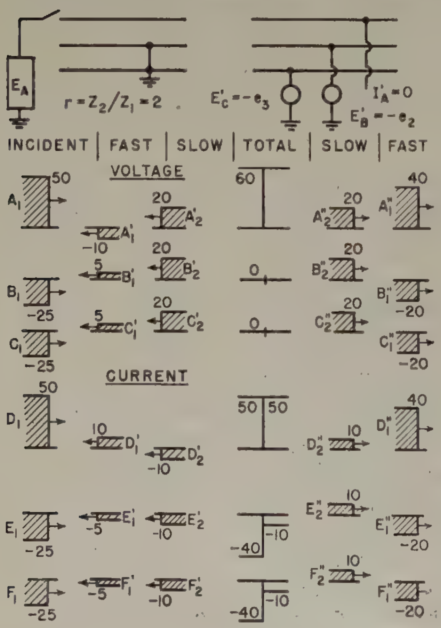

Figure 1. Wave components

The equations derived for determining the initial surge components also can be applied to the equivalent generators to determine the reflected components. Both slow and fast components are shown in Figure 1, to be produced at the fault. The slow components are equal on all three conductors; the fast components again have a sum equal to zero. The ratios of voltage to current are determined by separate characteristic impedances for the slow and fast components. Generally, Z_2, the characteristic impedance of the slow wave, is larger than Z_1 for the fast wave; the ratio of Z_2 to Z_1 has been taken equal to two as shown in Figure 1.

The transmitted waves are a superposition of the incident waves and those produced by the equivalent generators. The total values at the fault include those imposed: zero voltage on two conductors and no change of current on the third. The reflection coefficient, the ratio of reflected fast wave to incident fast wave, is −0.20 on each phase; the transmission coefficient is 0.80.

Many similar cases have been considered, since faults produce discontinuities in a variety of combinations; also the reflections vary with the disposition of the original surges among the conductors, depending on the nature of their origin. Calculations of reflections show close correlation with test results. The methods of analysis permit account to be taken of finite fault resistance, and also of dissymmetry at a fault such as produced by a broken conductor with one end grounded.

In fault locators where surges are applied to a line to obtain reflections, the scheme for applying surges may determine whether reflections are obtained. Such a system is effective only to the extent of the fast waves produced, and only where the fast waves in each case are such as to produce reflections for the types of faults to be recorded. The coupling system used in a fault locator to receive waves from a fault is to be judged by a criterion dependent on its response to the arrival of fast waves.

Digest of paper 51-312, "Traveling Wave Relations Applicable to Power-System Fault Locators," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

L. J. Lewis is with the University of Washington, Seattle, Wash.

Polyethylene for Wire and Cable

V. T. WALLDER

The use of polyethylene as a cable sheath is discussed in the light of difficulties encountered during actual field use. Protection against weathering is one problem; another is stress cracking when the polyethylene is subjected to certain environments such as soaps, alcohols, and wetting agents.

POLYETHYLENE NOW CAN BE said to have reached its maturity with ample realization of many of the promises and predictions made for it when it was first announced by the Imperial Chemical Industries of Great Britain[1] 18 years ago. Among the early uses of polyethylene was that of a dielectric and a great impetus to its early growth was the need, during World War II, for a dielectric with good dielectric properties over a wide range of frequencies. Its use in this field is well known[2–5] and today accounts for a considerable percentage of total consumption. One of the first uses for polyethylene in this country[6] was as the dielectric in coaxial telephone cable installed in 1939 between Baltimore and Washington and it has now become the standard dielectric for low-loss telephone cable.

In 1945 the demands for telephone service far exceeded the capacity of the prewar telephone plant to supply them and it became necessary to produce cable in an amount and at a rate which had never been realized before. Sinclair[7] pointed out that the quantity of cable needed for this expansion was almost double the amount of cable produced for the Bell System during the 1929 prewar peak. The traditional sheath material for communications cable always had been lead but with the expansion of other uses, such as storage batteries and the absence of discoveries of new lead deposits, it became apparent that there would not be sufficient lead to sheath cable to fill the demand for increased telephone service.

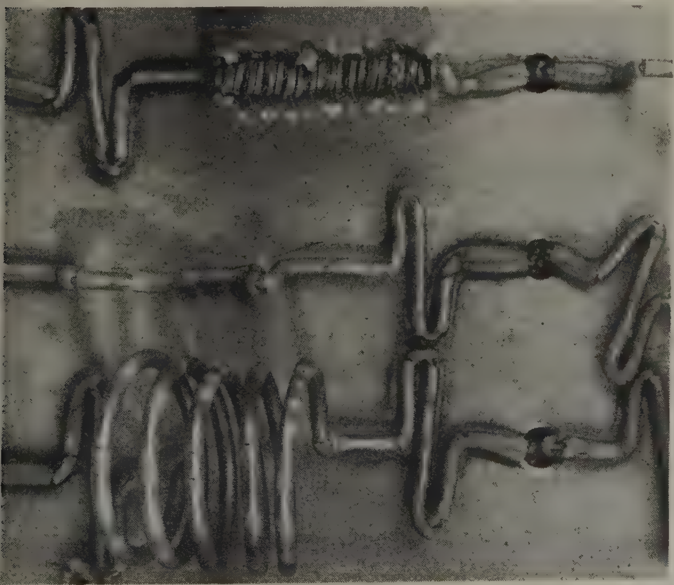

Figure 1. Unpigmented polyethylene insulated wire after 29 months' exposure in northern New Jersey

The Bell Telephone Laboratories has been interested in the performance of polyethylene as a mechanical protection, particularly applied to wire and cable coverings, and as early as 1941 compounding and aging studies on polyethylene were begun. This work has furnished sufficient background on the behavior of polyethylene to allow its choice as a supplement to lead in exchange cable sheath. To date thousands of miles of cable have been manufactured with a polyethylene sheath and its field performance generally has been good.

This article will discuss some of the difficulties experienced in the development of polyethylene as a cable sheath and how these have been overcome.

OUTDOOR WEATHERING

EARLY TESTS ON polyethylene showed that in an unprotected state its resistance to sunlight was very poor. Figure 1 shows the appearance of a polyethylene insulated wire after 29 months' exposure in New Jersey. The first cracks in these specimens occurred in 6 months. This brittleness, resulting from oxidation catalyzed by the ultraviolet energy present in ordinary sunlight, is accompanied by gross chemical changes, principally chain scission, resulting in lowered molecular weight, and cross-linking, resulting in a more insoluble polymer. The net result of these changes is a brittle material having little strength and greatly impaired dielectric properties arising from the oxygen introduced in the process of weathering. This type of failure, in which a chemical change takes place, must be distinguished from that produced by certain environments which will be discussed later.

Since the deterioration of polyethylene observed on outdoor exposure is produced by short wavelength radiation, barriers or screens which would prevent such energy from being absorbed by the polyethylene were investigated. So-called ultraviolet screens and both black and nonblack inorganic fillers have been evaluated and although all of these materials produce an improvement in outdoor aging resistance only carbon black, when properly selected and incorporated in the polyethylene, produces a compound having sufficiently long life for outdoor wire use.

Essential text of a conference paper presented at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26. Recommended by the AIEE Committee on Insulated Conductors.

V. T. Wallder is with the Bell Telephone Laboratories, Inc., Murray Hill, N. J.

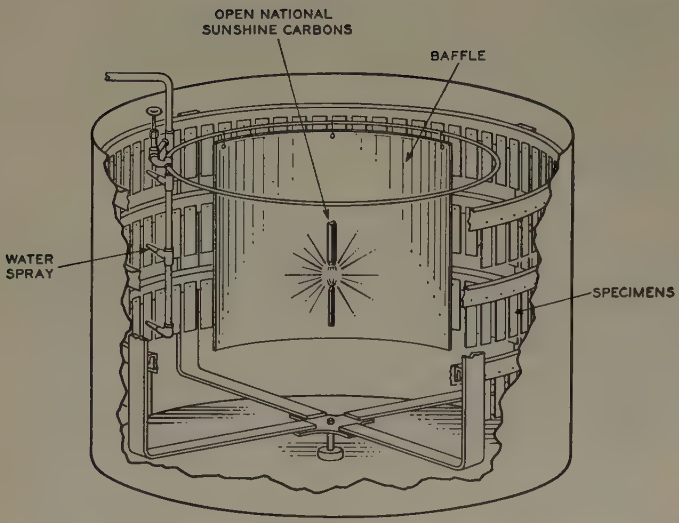

Figure 2. Modified X-1-A accelerated weathering unit

With the development of such long-life polyethylene compounds it became necessary to develop accelerated aging tests which could be carried out in a reasonable period and which could be related to outdoor performance. Details of such equipment are given in a previous publication[8] and consist primarily of exposure of the samples to a bare carbon arc with water spray. Figure 2 shows such equipment. This equipment gives good correlation with outdoor behavior. Numerous investigators have used the change in physical properties and dielectric properties, particularly power factor, as a criterion of aging. Since one of the marked changes which polyethylene undergoes when exposed to light is a loss in flexibility which becomes progressively worse until brittleness ensues and since this property, particularly at low temperatures, is of importance in a wire and cable material that will be exposed to the vagaries of climate occurring in the United States, it appeared attractive to examine low-temperature brittleness as a criterion of aging in polyethylene.

Table I shows the results of accelerated aging on standard extrusion-grade polyethylene containing no additives and having a 3-minute Williams plasticity index at 130 degrees centigrade of 55. The polyethylene was exposed in the accelerated test unit for periods of time up to 155 hours and stress-strain, dielectric, and low-temperature brittleness properties determined. The data show that low-temperature brittleness can detect a change from a material originally flexible at −76 degrees centigrade to one completely brittle at this temperature in less than 16 hours of aging. In the same period of time the stress-strain and dielectric data show substantially smaller changes. Based on these data, in subsequent evaluation of the effects of aging on polyethylene, low-temperature brittleness has been used as the criterion of change. In some of the work reported here actual brittle points were determined while recent data used the statistical approach shown by Smith and Dienes[9] to be more significant because of the slope of the per cent failure-temperature curve.

NATURAL VERSUS ACCELERATED AGING

FIGURE 3 COMPARES the natural and accelerated aging of the polyethylene compounds in Table II. It will be noted that the ordinates have been scaled so that 100 hours of accelerated aging equals 1 year of outdoor exposure. On this basis fairly good agreement occurs between the natural and accelerated aging exposures and this relation of 100 hours' accelerated aging to one year outdoors has been used to extend the accelerated aging results into terms of outdoor weather performance. It is felt that at least up to 2,000 hours of accelerated exposure the correlation is not excessively conservative. Compounds *B* and *D* are still under test after $10\frac{1}{2}$ years. Compound *B* remains flexible to −25 degrees centigrade and Compound *D* to −35 degrees centigrade after this period.

The only effective light screen for polyethylene is carbon black, although Burgess[10] has reported aging resistance equivalent to carbon black for some nickel chelates. However, these are almost black in color and, although of interest theoretically, would offer no practical advantages over

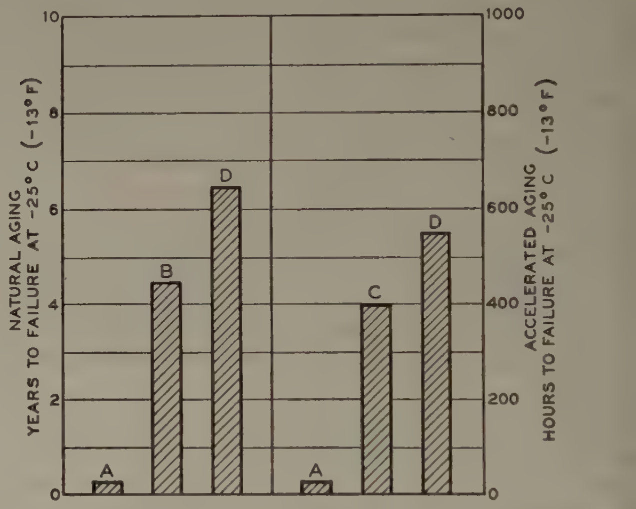

Figure 3. Natural versus accelerated aging of polyethylene compounds

Table I. Comparison of the Effect of Accelerated Aging on the Low-Temperature Brittleness, Stress-Strain, and Dielectric Properties of Polyethylene

	Hours Accelerated Aging						
	0	16	23	48	97	129	155
*Low Temperature Brittleness**							
Per cent of samples passing at:							
0 degrees centigrade	100	100	100	100	20	20	
−25 degrees centigrade	100	100	100	0	0	0	
−35 degrees centigrade	100	100	.....	0	0	0	
−45 degrees centigrade	100	100	0	0	0	0	
−60 degrees centigrade	100	40	.....	0			
−76 degrees centigrade	100	0	0	0	0	0	
*Stress-Strain***							
Tensile strength, pounds per square inch	1,890	1,715	1,600	1,330	1,315	1,310	1,300
Elongation, per cent	715	640	565	265	125	105	110
Stress at 100 per cent E, pounds per square inch	1,255	1,255	1,260	1,310	1,310	1,310	1,300
*Dielectric Properties****							
Dielectric constant at 50 megacycles	2.28	2.27	2.25	2.28	2.29	2.30	2.31
Power factor at 50 megacycles, per cent	0.02	0.05	0.06	0.11	0.23	0.28	0.27
Surface resistivity, 10^8 megohms	210	200	65	49	39	25	5

* American Society for Testing Materials *D-746-44T*.

** American Society for Testing Materials *D-412-41*.

*** American Society for Testing Materials *D-150*.

carbon black. The resistance to aging of any given polyethylene-carbon black compound depends upon three factors: 1. type and particle size of the carbon black; 2. concentration of the carbon black; and 3. dispersion of the carbon black in the polyethylene.

Figure 4 shows the effect of carbon black type on accelerated aging of polyethylene for 1-per cent concentrations of five commercial carbon blacks. Furnace type blacks such as Thermax and Philblack *A* have relatively little advantage as light screens but among the channel blacks resistance to aging increases with decreasing particle size.

The dependance of aging on carbon black concentration is shown in Figure 5 where age resistance is shown to increase with increasing Kosmos *BB* carbon black concentration until a loading of 2 to 5 per cent is reached. Higher amounts of carbon black or other fillers produce serious effects on such properties as tensile strength, elongation, modulus, brittleness at low temperature, and dielectric properties. Greater light protection than that afforded by 2-per cent carbon black can be obtained through a surface coating of aluminum powder. Mixing of aluminum powder directly in unpigmented polyethylene produces relatively little improvement. Addition of aluminum to a carbon black containing compound has produced some increased protection over polyethylene containing only carbon black.

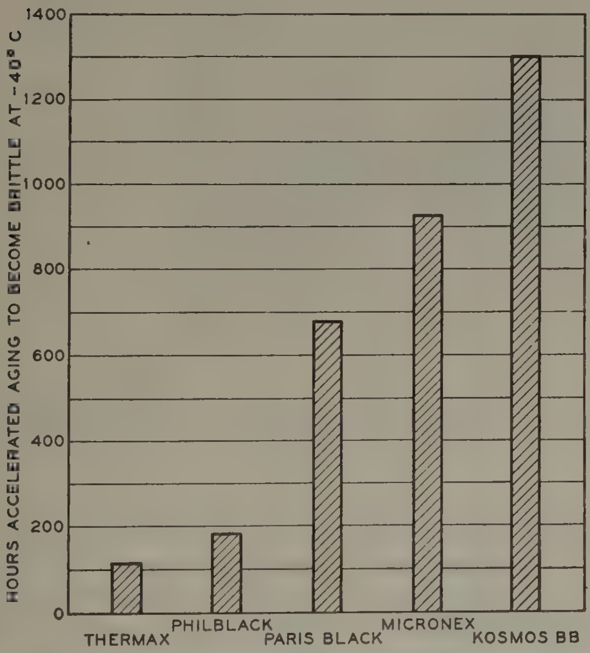

Figure 4. Effect of 1-per cent concentrations of five carbon blacks on accelerated aging of polyethylene

Table II. Polyethylene Compounds Tested

	A	B	C	D
Polyethylene resin	100.00	94.34	94.34	98.00
Carbon black-paris		0.94	0.94	2.00
Polyisobutylene		2.36	2.36	
Hydrocarbon wax		2.36	2.36	
Total	100.00	100.00	100.00	100.00
Form of sample	Molded Sheet	Wire Insulation	Molded Sheet	Molded Sheet
Exposure location	Northern N. J.	Miami, Fla.		Northern N. J.
Types of resin	American	British	American	British

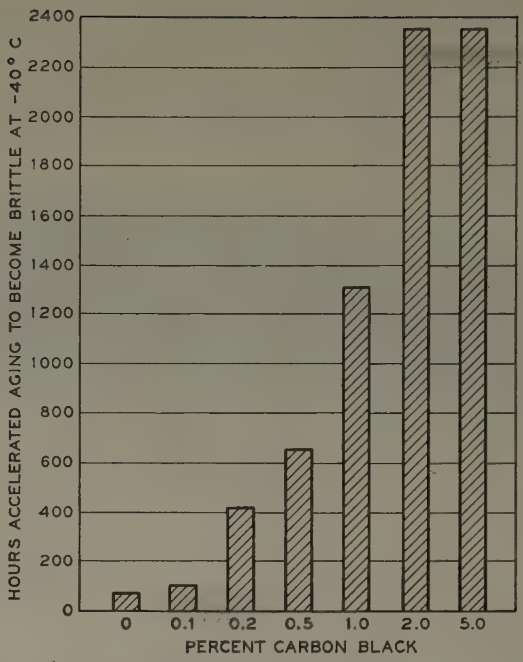

Figure 5. Effect of carbon black concentration on accelerated aging of polyethylene

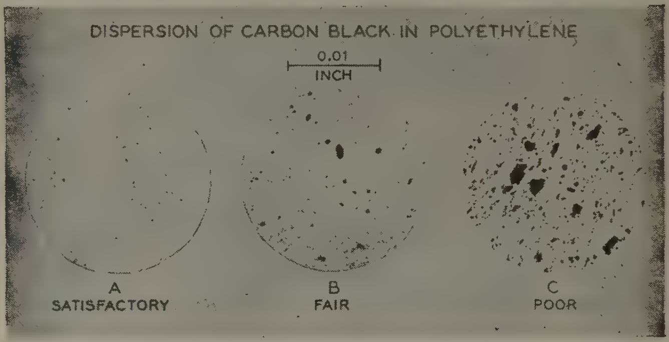

Figure 6. Dispersion of carbon black in polyethylene (×100)

Provided the proper particle size and concentration of carbon black is selected, maximum weather resistance cannot be obtained unless the carbon black is dispersed in the polyethylene so that most efficient use is made of its small particle size. Figure 6 shows the effect of dispersion where the accelerated aging resistance of 1-per cent Kosmos *BB* dispersions in polyethylene range from 100 hours for the poorly dispersed compound through 600 hours for the fair dispersion to 1,800 hours for the well-dispersed sample.

Thus by well dispersing in polyethylene a fine particle size carbon black in a suitable concentration a compound can be prepared which, on the basis of outdoor exposure tests carried out for 10 years together with accelerated tests, should perform satisfactorily in aerial service for at least 20 years.

ENVIRONMENTAL CRACKING

When the results of the foregoing work were applied to commercial cable it was expected that aerial cable would constitute the greatest hazard. However, after this type of cable, named alpeth from its sheath construction of *al*uminum and *polyeth*ylene, had been installed in underground ducts for about a year a number of trouble cases were reported where the polyethylene sheath had cracked.

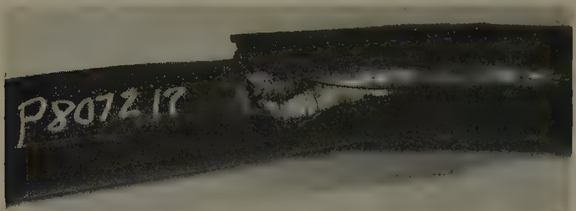

Figure 7. Environmental stress crack in polyethylene cable sheath

The cracks were of such size that the cables quickly failed due to the entrance of water. Figure 7 shows such a field cable failure.

Exhaustive examination of the material adjacent to the cracked areas showed that no chemical change in the polyethylene had occurred. It was found that the cracks usually occurred at a point where the cable had been bent severely. However, strenuous bending and twisting in the laboratory caused no cracking until the effects of certain, principally liquid, environments such as alcohols, soaps, and wetting agents were examined. Cable when sharply bent and then treated with one of these materials could be made to crack in a few minutes of exposure to the environment. It thus became apparent that when polyethylene was subjected to polyaxial stress and exposed to certain environments its behavior was considerably different from exposure under uniaxial stress. Without the presence of an environment the conditions required for polyaxial stress failure are rather critical[11] and are not expected to be encountered frequently. In the presence of active environments cracking will occur under stresses which polyethylene ordinarily will resist indefinitely.

Richards[12] has pointed out that embrittlement of low molecular weight resins occurs in the presence of mobile polar liquids such as acetone or alcohol and that higher molecular weight grades of polyethylene did not suffer from this treatment. In a previous publication[13] it has been shown that for American polyethylene cracking occurs almost instantaneously for low molecular weight resins, while for extrusion grades having a molecular weight of about 20,000 cracking occurs in hours or days depending upon the activity of the environment. Since this cracking is dependent upon the presence of adverse environments such as alcohols, soaps, wetting agents, and the like the phenomenon has been termed "environmental cracking." Environmental cracking is similar in many of its aspects to the familiar solvent crazing occurring in polystyrene and polymethyl methacrylate[14,15] where the combination of certain solvents and polyaxial stress produces crazing.

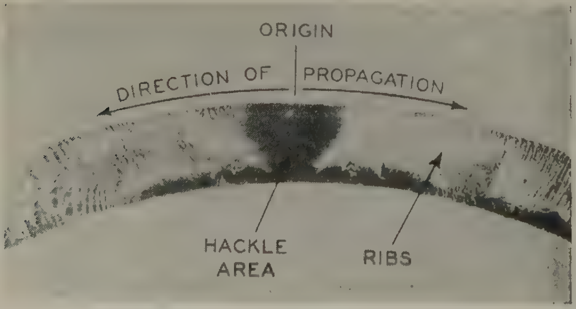

Figure 8. Magnified view of the face of a sheath crack

In the case of cable failures, such as that shown in Figure 7, examination of the surfaces of the crack will reveal superficial features analogous to those occurring when a piece of glass is fractured. Oughton,[16] in discussing glass fractures, has outlined a method of characterizing the crack surfaces that allows one to determine the point of origin of the crack, the direction in which the crack propagated, and areas of high shearing stresses. In Figure 8 this method has been applied to a polyethylene crack. The fine, almost imperceptible "hackle lines" radiate from a point which is the origin of the crack and the general hackle area has been one of high shearing stress. The clearly distinguishable curved "rib marks" on either side of the hackle area indicate the direction of propagation of the crack in a direction approaching the rib marks from the concave side and leaving on the convex side.

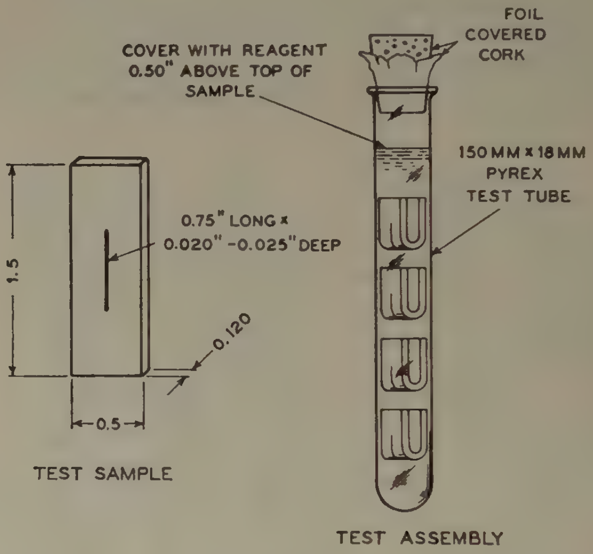
COVER WITH REAGENT 0.50" ABOVE TOP OF SAMPLE
FOIL COVERED CORK
150 MM x 18 MM PYREX TEST TUBE
0.75" LONG x 0.020" -0.025" DEEP
1.5
0.120
0.5
TEST SAMPLE
TEST ASSEMBLY

Figure 9. Test specimen and apparatus for determining crack resistance

TEST METHOD

FOLLOWING CLASSIFICATION of the basic factors of environment and polyaxial stress involved in the failure of alpeth cable sheath, the types of environment producing cracking, methods of improving the crack resistance of polyethylene, and the effect of thermal treatment on crack resistance were examined using a test method which reproduces on a laboratory basis the cracking occurring on cable in the field.

This test involves exposing a specimen of polyethylene containing a razor blade slit as shown in Figure 9 to the action of a cracking agent. In most cases tests are made at 50 degrees centigrade except for materials which would be volatile at this temperature. By selecting a standard sample of polyethylene the effect of environments can be evaluated, while by selecting a suitable environment as a standard the effect of molecular weight, compounding, and other resin variables can be examined. Figure 10 shows a specimen before and after cracking.

Some 300 environments have been studied for their effect on polyethylene. In the case of active environments failure occurs rapidly within minutes or a few hours. However it is more difficult to determine when an environment is inactive. Before classifying a material as inert tests were run from 100 to 200 days. Table III summarizes the results of these tests. It will be noted that the inactive environments in general include materials of rather high molecular weight particularly among the organic members. This also applies to some extent among the active materials where activity of cracking appears to decrease with increasing molecular weight.

The metallic soaps, sulfated and sulfonated alcohols, alkanolamines, and polyglycol ethers were found to be among the most active cracking agents, causing failure in a few minutes even when diluted as much as 1,000 to 1. Polybutenes of moderate molecular weight were among the less active environments, requiring a period of several weeks to produce cracking. The behavior of the active cracking agents is unique in that they are absorbed by the polyethylene in amounts of only a few tenths of a per cent.

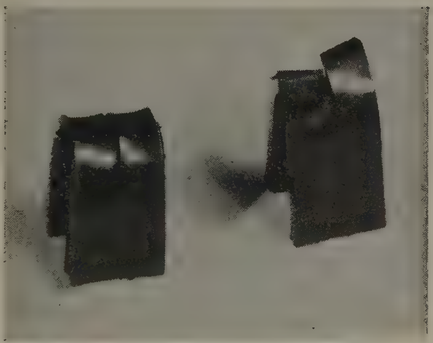

Figure 10. Appearance of stressed specimen before cracking (left) and after cracking (right)

As a cable sheath, polyethylene is installed in underground ducts as well as aerially and, in the former case, can come into contact with various gaseous environments such as carbon dioxide, hydrogen sulfide, natural gas, and so forth. Tests with methane, propane, hydrogen sulfide, carbon monoxide, carbon dioxide, and air at 25 degrees centigrade and under a pressure of 3 pounds per square inch in the absence of water did not cause cracking. However, under different conditions such as in the presence of water or at higher temperatures gases such as methane or propane might become active and are therefore viewed with suspicion.

Table III. Effect of Various Materials on 55 Grade Polyethylene

Bell Telephone Laboratories Crack Resistance Test

Active Environments

Aliphatic and aromatic liquid hydrocarbons.
Alcohols
Organic acids
Ester-type plasticizers

Vegetable oils
Animal oils
Mineral oils

Metallic soaps
Sulfated and sulfonated alcohols
Alkanolamines
Polyglycol ethers
Sodium and potassium hydroxide
Depolymerized rubbers
Polybutenes
Silicone fluids

Inert Environments

Water
Polyhydric alcohol
Sugars
Selected saponins
Hydrolyzed protein

Rosin
Selected asphalts
Paraffin wax
Bentonite
ABcid and neutral inorganic salts

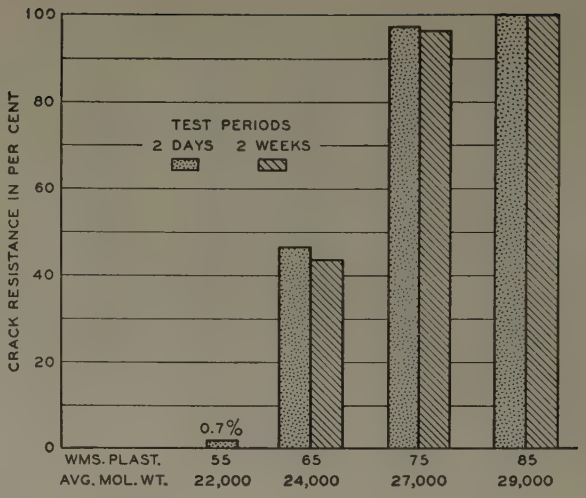

Figure 11. Effect of molecular weight on crack resistance

IMPROVING CRACK RESISTANCE

Certain of the factors involved in environmental cracking led to the suspicion that crack resistance should be dependent on the molecular weight of the base resin. Accordingly special samples of high molecular weight resins were obtained and examined for crack resistance. In this work Igepal *CA*, an alkylaryl polyethylene glycolether, was used as a cracking environment because of its stability and cracking activity. Resins ranging from the standard extrusion grade having a Williams 3-minute plasticity[17] at 130 degrees centigrade of 55 to high molecular weight resins with a plasticity of 85 were tested. The results given in Figure 11 represent the averages obtained on a large number of specimens in each group. The height of

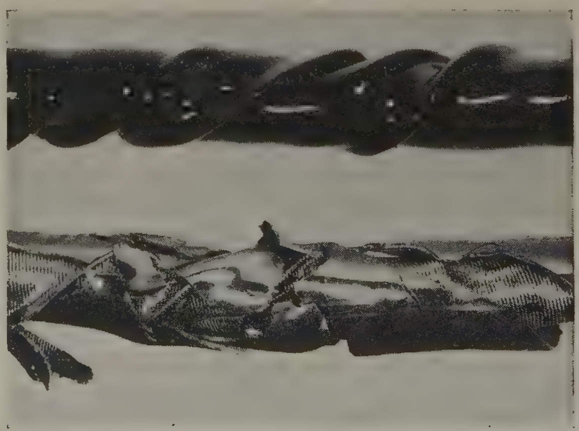

Figure 12. Examples of twisted cable treated with Igepal. Sheath of 77 grade resin (top), sheath of 55 grade resin (bottom)

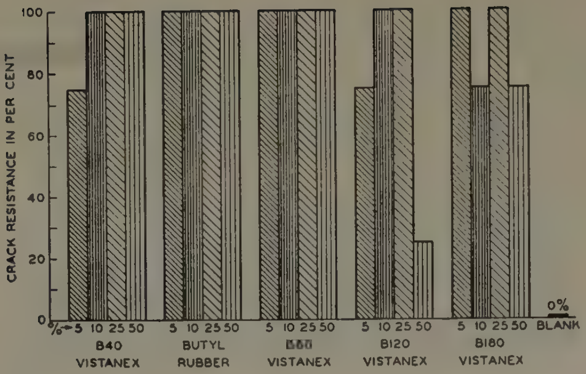

Figure 13. Effect of polyisobutylene on crack resistance of polyethylene

each column represents the percentage of specimens in each group which did not crack. Thus the commercial grade resin with a plasticity of 55 corresponding to a molecular weight of about 22,000 has a crack resistance of only 0.7 per cent after 2 days immersion in Igepal *CA*, indicating that 99.3 per cent of all the specimens in this group failed. In the 65 plasticity range over 40-per cent resistance was obtained while essentially complete freedom from cracking occurred for the 75 and 85 grades.

Figure 12 shows rather strikingly the improvement in crack resistance obtained through high molecular weight resin. Each cable was twisted through 540 degrees about its longitudinal axis and then coated with Igepal *CA* and stored at room temperature. The lower cable was sheathed with 55 grade standard extrusion polyethylene and cracked within a few days. The upper cable was sheathed with high molecular weight resin having a Williams plasticity of about 77 and showed no cracks in a 6 months' period.

Although other factors such as chain branching and molecular weight distribution are known to have an effect on environmental cracking of polyethylene, these data show that provided the average molecular weight of polyethylene is sufficiently high, a high level of crack resistance can be obtained.

The first compositions of polyethylene used for cable work contained polyisobutylene introduced primarily to improve extrusion properties. Wilson[18] has described its use in a submarine cable where 12.5 per cent of polyisobutylene was used. Since the addition of polyisobutylene to polyethylene reduces modulus it was felt that such blends should improve crack resistance by providing a molecular structure which would have a greater tendency to relax when stressed than in polyethylene.

The effect of the addition of polyisobutylenes of differing molecular weights and unvulcanized butyl rubber in various concentrations to polyethylene having a Williams plasticity of 54 is shown in Figure 13. Butyl rubber and polyisobutylenes of 40,000 (*B-40* Vistanex) and 80,000 (*B-80* Vistanex) molecular weight conferred almost complete protection on the polyethylene which without these materials showed extremely low crack resistance. The nonuniform results obtained with the higher molecular weight grades of polyisobutylene are believed to be due to the difficulty of incorporating these tougher polymers uniformly in the polyethylene. Although blends such as these markedly reduce the susceptibility of polyethylene to environmental cracking, increasing amounts of polyisobutylene will reduce tensile strength, modulus, tear strength, stiffness, hardness, and thermal resistance, and increase elongation. Resistance to weathering may be affected also. Up to the present such compounds have not been used for cable sheathing.

THERMAL HISTORY AND CRACK RESISTANCE

IT HAS BEEN FOUND that the thermal history to which polyethylene is exposed in its fabrication will affect its crack resistance. Thus the more rapidly a specimen is cooled the better will be its original resistance to environmental cracking. Poorest original crack resistance is found on well-annealed specimens. However when quenched samples are allowed to stand at room temperatures their crack resistance will degrade until a value is reached which is about equal to an annealed sample. Storage life appears to have little effect upon the crack resistance of annealed material.

The use of polyethylene for outside wire and cable primarily as a sheath material has resulted in an expanded field for a material originally of primary interest to cable engineers only as a dielectric. However with increasing knowledge concerning some of its shortcomings it is now possible to design compositions of polyethylene which can be expected to provide a cable sheath having characteristics allowing its use outdoors exposed to the weather and as underground cable.

REFERENCES

1. Improvements in or Relating to the Polymerization of Ethylene, **E. W. Fawcett, R. O. Gibson, M. W. Perrin, J. G. Paton, E. G. Williams.** British Patent *471,590*, 1937.

2. Polythene—Physical and Chemical Properties, **F. C. Hahn, M. L. Macht, D. A. Fletcher.** *Industrial and Engineering Chemistry*, American Chemical Society (Washington, D. C.), volume 37, June 1945, pages 526–33.

3. Polyethylene, **C. S. Myers.** *Modern Plastics* (New York, N. Y.), volume 21, August 1944, pages 103–07, 174, 176.

4. General Characteristics of Polyethylene, **J. W. Shackleton.** AIEE *Transactions*, volume 64, 1945, pages 912–16.

5. Polythene, **J. C. Swallow.** *Endeavour* (Birmingham, England), volume 3, January 1944, pages 26–31.

6. Polyethylene-Disc Insulators for Coaxials, **C. Kreisher.** *Bell Laboratories Record* (New York, N. Y.), volume 23, September 1945, pages 321–24.

7. Exchange Cable: The Drams of Post-war Production, **C. G. Sinclair, Jr.** *Bell Telephone Magazine* (New York, N. Y.), volume 27, summer 1948, pages 77–87.

8. Weathering Studies on Polyethylene, **V. T. Wallder, W. J. Clarke, J. B. DeCoste, J. B. Howard.** *Industrial and Engineering Chemistry*, American Chemical Society (Washington, D. C.), volume 42, November 1950, pages 2320–25.

9. An Improved Low-Temperature Brittleness Test, **E. F. Smith, G. J. Dienes.** *Bulletin*, American Society for Testing Materials (Philadelphia, Pa.), October 1948, pages 46–49.

10. Photo-oxidation and Stabilization of Polyethylene, **A. R. Burgess,** Paper presented at the National Bureau of Standards Symposium on Polymer Degradation Mechanisms in Washington, D. C., on September 25, 1951. To be published by the National Bureau of Standards, Washington, D. C.

11. Complex Stressing of Polyethylene, **I. L. Hopkins, W. O. Baker, J. B. Howard.** *Journal of Applied Physics*, American Institute of Physics (New York, N. Y.), volume 21, March 1950, pages 206–13.

12. The Phase Equilibria Between a Crystalline Polymer and Solvents, **R. B. Richards.** *Transactions* of the Faraday Society (Aberdeen, Scotland), volume 42, January 1946, pages 10–28.

13. Cracking of Stressed Polyethylene, **J. B. DeCoste, F. S. Malm, V. T. Wallder.** *Industrial and Engineering Chemistry*, American Chemical Society (Washington, D. C.), volume 43, January 1951, pages 117–121.

14. Process for Inhibiting Cracking of Polymeric Bodies, **W. O. Baker.** United States Patent *2,373,093*, 1945.

15. Crazing of Cast Polymethyl Methacrylate, **E. W. Russell.** *Nature* (London, England), volume 165, January 21, 1950, pages 91–96.

16. Analysis of Glass Fractures, **C. D. Oughton** *The Glass Industry* (New York, N. Y.), volume 26, February 1945, pages 72–74, 90.

17. Plasticity and Recovery of Rubber and Rubberlike Materials by the Paralled Plate Plastometer. American Society for Testing Materials (Philadelphia, Pa.), ASTM Specification *D-926-47T, 1947*.

18. Submarine Cable, **H. F. Wilson.** *British Plastics* (London, England), volume 20, January 1948, pages 20–26.

Short-Circuit Calculation on Secondary Networks

J. ZABORSZKY
MEMBER AIEE

C. F. CROMER

CALCULATION OF short-circuit currents on secondary networks is inherently lengthy and tedious because a very large number of electric circuits are involved.

In view of this there is need for a simple approximate calculation to yield values without excessive work and with sufficient accuracy This is especially important for the purpose of the preliminary engineering and economic design where a large number of systems with different components are considered.

An actual secondary network is never entirely uniform because of local irregularities of the street pattern and load distribution. But representation by a uniform grid is possible as an approximation. Here this approximation is carried one step further. The uniform grid is replaced by a thin conducting plate (I in Figure 1) which is equivalent to the grid in the sense that corresponding sections of grid and plate have equal impedances, except possibly for such differences as result from the sectionalized nature of the grid. In a similar way the transformers are represented equivalently in Figure 1 by plate II. This latter plate must be homogeneous but nonisotropic. It is uniform but conducts current in the vertical direction only. If a physical picture of this situation is desired plate II may be visualized as consisting of very thin insulated vertical wires packed solidly together.

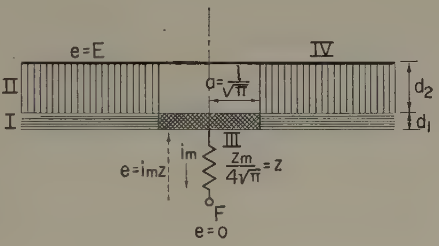

Figure 1. Equivalent of the secondary network distribution system. Resistive plates I and II represent the secondary grid and the transformers respectively. Ideally conductive plate IV represents the feeder network. The void above the ideally conductive electrode III eliminates the contribution of the local transformer to the short-circuit current

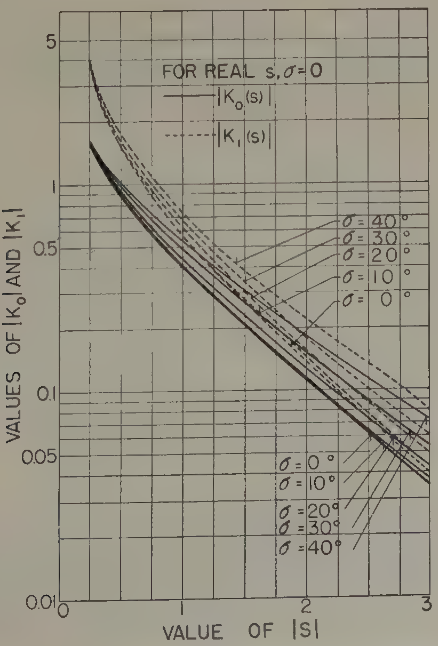

Figure 2(A). Chart showing magnitude of $K_0(s)$ and $K_1(s)$ for complex $s=|s|\underline{/-\sigma}$

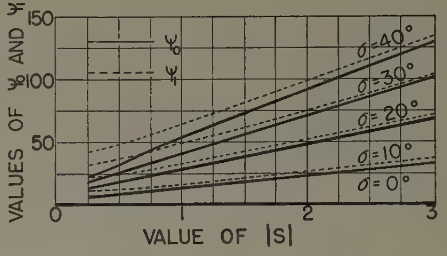

Figure 2(B). Chart showing angle of $K_0(s)$ and $K_1(s)$ for complex $s=|s|\underline{/-\sigma}$

It is assumed that the voltage of the feeder network is not affected by the short circuit of the secondary network, and accordingly the feeder network is represented by the perfectly conductive plate IV in Figure 1.

The contribution of the local transformer to the short-circuit current is eliminated by leaving a void in plate II above electrode III. Electrode III is a perfectly conductive body while impedance z represents the impedance of the network in the immediate vicinity of the fault.

Solving the differential equation of the equivalent system the following formula can be derived for the ratio of the short-circuit current contributed by the network to that contributed by the local transformer.

$$\frac{i_n}{i_t}=\frac{4\sqrt{\pi}}{\frac{z_m}{z_t}}\,\frac{K_1(s)}{K_1(s)+2\sqrt{\frac{z_t}{z_m}}\,K_0(s)}$$

where $s=\sqrt{\frac{z_m}{\pi z_t}}$; z_m=impedance of one (block length) section of secondary main; and z_t=impedance of one network transformer.

Values of functions $K_0(s)$ and $K_1(s)$ can be taken from Figure 2. If $s=|s|\underline{/-\sigma}$ is complex, K_0 and K_1 will be complex also. The magnitudes of K_0 and K_1 are given in Figure 2(A) while their angles are given in Figure 2(B).

The equation presented refers to the case when a transformer is located at each street corner. While local irregularities of the actual secondary network are not considered, the accuracy will suffice for many purposes. Because of its simplicity the method appears to be well suited to supply data for preliminary design where a number of systems with different components are considered.

Digest of paper **51-333**, "Fast, Approximate Short Circuit Calculation on Secondary Networks," recommended by the AIEE Committee on Transmission and Distribution and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

J. Zaborszky is with the School of Mines and Metallurgy, University of Missouri, Rolla, Mo., and **C. F. Cromer** is with Westinghouse Electric Corporation, East Pittsburgh, Pa.

Analysis of the Drag-Cup A-C Tachometer

R. H. FRAZIER
FELLOW AIEE

DRAG-CUP a-c tachometers have very important uses as velocity feedback elements in computing machines, automatic pilots for planes and missiles, automatic fire-control mechanisms, and in other military or industrial control applications. The tachometer is essentially a 2-phase induction generator designed so that when one phase of the stator is energized from a constant-amplitude constant-frequency voltage source the other stator phase gives a voltage of amplitude closely proportional to the speed at which the cup is driven and a phase nearly fixed with respect to the supply voltage, over a substantial speed range.

When applications of this type of tachometer require extreme accuracy, thorough analysis of all the details that influence errors is essential to favorable design and utilization. One such application is in the flight simulator in the Dynamic Analysis and Control Laboratory at the Massachusetts Institute of Technology. An extensive analytical and experimental study was conducted.

An equivalent circuit for the tachometer, derived by use of 2-phase symmetrical components, is shown in Figure 1. Subscripts m and a apply, respectively, to main-winding and auxiliary-winding quantities, subscripts 1 and 2 apply, respectively, to stator and rotor quantities, and subscripts f and b apply, respectively, to the forward and backward sets of symmetrical components.

$$Z_{1m}=r_{1m}+jx_{1m} \tag{1}$$

$$Z_d=\frac{1}{2}\left(\frac{Z_{1a}}{\epsilon^2}-Z_{1m}\right) \tag{2}$$

x_{1m} is the leakage reactance of the main winding with respect to the rotor plus any external series reactance, r_{1m} is the resistance of the main winding plus any external series resistance, Z_{1a} is the leakage impedance of the auxiliary winding plus any external load impedance, and α is the turns ratio, auxiliary to main winding. In the remainder of the circuit, x_ϕ is the magnetizing reactance, x_2 is the leakage reactance of the rotor with respect to the main winding, r_2 is the rotor resistance, and s is the per-unit slip. All impedances are referred to the main winding.

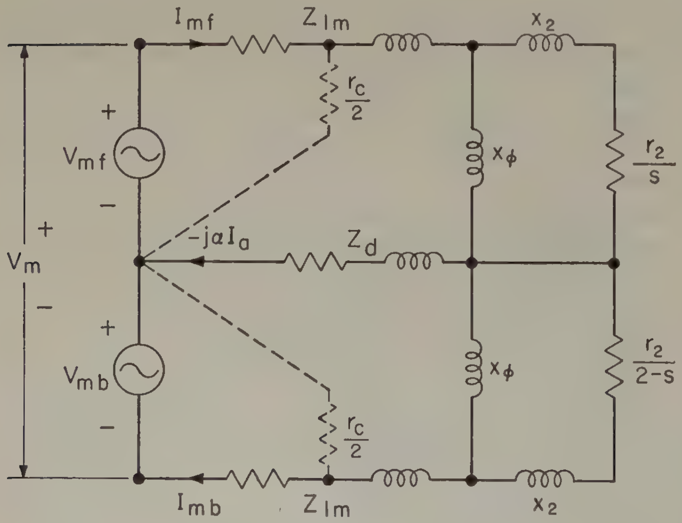

Figure 1. Equivalent circuit of 2-phase induction machine

For the simple case of an open-circuited auxiliary winding ($Z_{1a}=\infty$, $Z_d=\infty$), the voltage V_L of the signal winding is

$$\frac{V_L}{V_m}=\frac{\alpha n}{A_1+jB_1+(A_2-jB_2)n^2} \tag{3}$$

in which

$$A_1=(b-a^2b)x_{11}+2abr_{1m}+a \tag{4}$$

$$B_1=2abx_{11}-(b-a^2b)r_{1m}-1 \tag{5}$$

$$A_2=(a^2bx_{11}-a)^2 \tag{6}$$

$$B_2=a^2br_{1m}{}^2 \tag{7}$$

$$a=x_{22}/r_2 \tag{8}$$

$$b=r_2/x_\phi{}^2 \tag{9}$$

$$x_{11}=x_\phi+x_{1m} \tag{10}$$

$$x_{22}=x_\phi+x_2 \tag{11}$$

and n is the per-unit speed based on synchronous speed. Expressions similar to equation 3 can be derived for various conditions of load on the auxiliary windings, and the effects of core loss can be approximated by use of r_c.

Use of these expressions facilitates the selection of favorable proportions for the electromagnetic parameters in the initial design, and the study of errors as functions of speed, source voltage and frequency, temperature, and dissymmetry and inhomogeneity of parts. The expressions also readily make evident the influence of the various parameters in determining magnitude and phase of output voltage, so that procedures in calibrating and adjusting the tachometer can be orderly. Schemes of minimizing or compensating for various errors have been devised and several systematic and convenient methods of calibration with the aid of terminal adjusting networks have been developed. In particular, terminal networks have been devised that theoretically completely eliminate the speed errors; practically, speed errors probably can be reduced to about 0.01 per cent for magnitude and 0.01 degree for phase over a range from zero to several thousand revolutions per minute. For such accuracy close control of supply voltage and frequency, ambient temperature, symmetry, and homogeneity of the cup is essential.

Digest of paper 51-348, "Analysis of the Drag-Cup A-C Tachometer by Means of 2-Phase Symmetrical Components," recommended by the AIEE Committee on Computing Devices and approved by the AIEE Technical Program Committee for presentation at the Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

R. H. Frazier is with the Massachusetts Institute of Technology Dynamic Analysis and Control Laboratory, Cambridge, Mass.

The Role of Corona Discharge in the Electrical Precipitation Process

H. J. WHITE
MEMBER AIEE

With smoke abatement a major problem in many industrial areas, the electrostatic process of cleaning smoke-laden air deserves a better understanding by engineers. Various aspects of this process, with emphasis on the part played by the corona discharge, are discussed.

IT IS A CURIOUS and perhaps indicative fact that the basic property of the corona discharge in cleaning smoke-laden air was discovered early in the nineteenth century,[1] many years before the first scientific study of the corona[2] itself was made. However, the practical development and large-scale application of the electrical precipitation principle to the removal of dusts and fumes from industrial gases was not possible until high-voltage means became available for producing the large amounts of corona power necessary.[3] Similarly, many of the basic advances and improvements in electrical precipitation have resulted from or coincided with the development of improved means for providing high-voltage unidirectional current or in controlling and modifying the corona discharge.

The general method of producing and utilizing the corona discharge in the precipitation process is illustrated in Figure 1. High-voltage unidirectional current is supplied by means of a step-up transformer and rectifier to the fine wire and coaxial cylinder corona electrodes. The corona sheath which forms over the wire surface acts as a copious source of unipolar gas ions which are attracted to the outer cylinder and produce a dense concentration of ions throughout the whole gas space between the electrodes. Particles carried in suspension in the gas stream are rapidly charged by ion bombardment as they enter the corona discharge space, and then are caused to collect or to precipitate on the surface of the outer cylinder by the intense electric space-charge field of the gas ions. The Coulomb force on the suspended charged particles in a precipitator is very large and accounts for the great effectiveness and advantage of the process.

Although many means are available for producing ions for particle charging, such as, for example, radioactivity, flame ionization, and thermal ionization, none of these compares in effectiveness with the corona discharge. Capacitor-plate or ion-free fields may be used in place of the space-charge corona field to effect precipitation of previously charged particles as is done in the so-called 2-stage precipitator. This arrangement is particularly applicable to the cleaning of ventilating air because it is possible to keep the generation of ozone in the precipitator to satisfactorily low levels, but is less satisfactory than the corona field for the cleaning of most industrial gases.

Electrical precipitation represents by far the largest practical application of the corona. For example, a precipitator cleaning the gas from a large modern power boiler of 1,000,000 pounds per hour steaming rate will have about 35,000 feet of corona discharge wire and will use about 40 kw of high-voltage d-c power in the corona discharge. The total corona power used in electrical precipitation today throughout the United States may be estimated at something like 50,000 kw, a very substantial figure in the realm of electric gas discharge applications.

CORONA DISCHARGE IN ELECTRIC PRECIPITATORS

ELECTRICAL PRECIPITATION requires the use of the unipolar corona discharge, that is, the discharge must occur from only one of the electrodes and only d-c or unidirectional currents can be used. A-c corona produces oscillating motions of the suspended particles and particle collection is slow. The d-c corona, on the other hand, produces a steady force driving the particles toward the passive electrode and collection is rapid.

The corona discharge electrodes used in practice include round wires, square-twisted rods, and various types of prong electrodes. The passive or collecting electrodes are

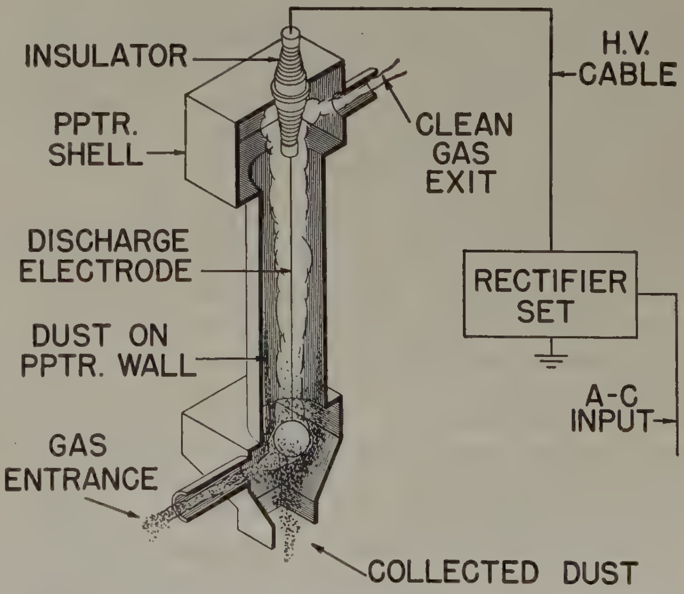

Figure 1. General method of producing and utilizing corona discharge in electrostatic precipitation

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Full text of a conference paper, "The Role of Corona Discharge in the Electrical Precipitation Process," recommended by the AIEE Subcommittee on Electrical Properties of Gases and presented at the AIEE Winter General Meeting, New York, N. Y., January 22–26, 1951.

H. J. White is with the Research Corporation, Bound Brook, N. J.

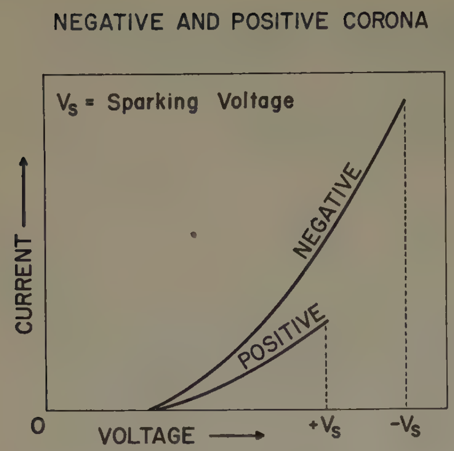

Figure 2. Representative current-voltage characteristics for positive and negative corona in air

usually pipes of 6- to 15-inch diameter, plates arranged in parallel to form ducts of 6- to 12-inch spacing, and the so-called shielded-pocket types which are designed to prevent re-entrainment of collected dust. Corona currents used range from 0.01 to 1 milliampere per foot of discharge electrode. Voltages are usually 30 to 100 kv, although much lower values of 10 to 15 kv are used for air-cleaning applications. Field strengths usually range from 3 to 6 kv per centimeter. Negative polarity corona is used for nearly all electrical precipitation work.

The voltage-current characteristic of the corona for a given electrode system depends on voltage waveform and polarity, on the kind of gas used, on the pressure and temperature of the gas, and on the contaminants (gaseous or suspended particles) present. Characteristic curves for both positive and negative corona discharge electrodes are shown in Figure 2. The important features to note are the much higher sparking voltage and current flow of the negative corona, both of which are favorable to electrical precipitation. Numerically, the sparking voltage for the positive corona frequently may be only half that for the negative corona under similar conditions, and, in addition, the positive corona tends to be unstable and sporadic. Cottrell's[3] earliest work on electrostatic precipitation in 1906 indicated the great superiority of the negative corona and experience since then has confirmed this result. The only exception to the use of the negative corona is in the field of air-cleaning where the positive corona is generally used because of its possibly lower ozone generation, as indicated by the work of Penney.[4]

MECHANISM OF THE NEGATIVE CORONA

The modern physical theories of corona are to be found in the literature.[5] A brief discussion limited to the negative corona will suffice for the purposes of this paper. The unipolar corona as used in electrical precipitation is a stable, self-maintaining gas discharge between a discharge electrode comprising a fine wire or series of sharp points and a smooth, extended-surface passive electrode such as a cylinder or plate. Electrode spacings are usually a few centimeters and gas pressures are of the order of magnitude of one atmosphere. Ionization processes are confined to the glow region in the strong electric field near the sharply curved wire. Most of the ionization is produced by free electrons which are accelerated to fairly high energy in this region and ionize by collision with molecules. Thus, each new electron released at or near the wire generates a large number of additional electron-positive ion pairs. The positive ions are drawn to the negative wire, while the electrons rapidly move toward the passive electrode and into a lower field region where they soon attach to gas molecules to form slow-moving negative ions in such gases as permit negative ion formation.

To produce a self-maintaining discharge a second ionization mechanism must be present to provide the necessary initiating electrons at or near the wire. This secondary mechanism appears to be release of electrons from the wire surface by impact of the positive ions, but could also be photoelectric effect. Metastable atoms are important in some gases such as helium or argon, but these gases are not ordinarily encountered in electrical precipitation. The beaded form of the negative corona may be explained on the basis of localized ionization mechanisms at the discharge wire surface. These mechanisms may be either positive ion impact on the electrode surface or photoelectric emission from ultraviolet radiation from the corona glow. In general, ion production would be most effective at points of low work function on the wire surface. As is well known, the work function of a gassy and contaminated surface is extremely spotty, so that the discharge would be concentrated in small areas corresponding to the beads or glow points which characterize the negative corona in most gases. In the case of impacting positive ions, the wire surface would tend to clean up locally, which in turn would raise the work function and cause the glow points to move somewhat erratically to neighboring points of lower work function. The more or less regular spacing of the beads which is commonly observed for the negative corona may be explained on the basis of mutual space-charge repulsion of adjacent beads.

The basic mechanism of the negative corona may be pictured then as follows. Electrons are released from the wire surface by positive ion impact or photoelectric emission. These electrons in moving through the strong field near the wire generate many new electrons and positive ions by molecular impacts. The electron swarm quickly moves to the lower field region where attachment to gas molecules occurs to form negative ions. The positive ions are accelerated to the wire and produce at least some of the necessary new electrons by positive ion impact at the wire surface. Probably photoelectrons also are produced at the wire surface by ultraviolet radiation from the corona glow. In the meantime, the negative ions in the lower field region are moving to the passive anode, and in so doing build up a dense cloud of unipolar ions which substantially fills most of the space between the discharge wire and surrounding coaxial cylinder. The integrated effect of this space charge is analogous to a large series resistor which sharply limits the ionizing field near the discharge wire and stabilizes the discharge. Under these circumstances, the current-voltage characteristic will rise rather slowly, because as the voltage is increased most of the voltage increment is used in overcoming the added space charge and only a small amount is effective in increasing ionization near the discharge electrode.

Electron attachment coefficients and negative ion mobilities vary greatly from gas to gas, and this, together with the variations which occur in the ionization coefficients, accounts for the wide range of corona characteristics met with in different gases. Corona current characteristics for the typical gases N_2, O_2, and CH_3Cl are shown in Figure 3.[6,7] Electrons do not attach to nitrogen molecules. Hence in this gas the negative space-charge effect will depend largely on the presence of foreign gas molecules which can form negative ions, but even with nitrogen of commercial purity the current rises very steeply with increasing voltage, as shown in Figure 3. Oxygen, on the other hand, readily attaches electrons and the space charge of the negative oxygen ions which accumulate in the passive region of the discharge is large. Electronegative gases, represented in Figure 3 by methyl chloride, attach electrons very strongly and the resultant quenching of the corona current is even more severe than in oxygen. In electrical precipitation practice the very steep characteristic of the nitrogen type seldom, if ever, occurs, but large variations such as represented by the differences between O_2 and CH_3Cl are common.

The negative wire corona in air under certain conditions may appear as a uniform glow around the wire, but usually appears as a series of glow points or tufts more or less evenly spaced along the length of the wire.[8] Increasing the current tends to increase the number of glow points without much affecting their intensity. As previously discussed, any given glow point tends to be unstable and will jump up and down the wire somewhat. Its intensity may also vary and the glow may even disappear for periods of seconds or longer. Oscilloscopic observation of current corresponding to a single glow point shows strong flickering corresponding to changes in visual intensity. Indeed, detailed studies of the corona show that it is characterized by intermittent current pulses which can be of quite high frequency. For a long wire having many glow points, these intermittent effects average out, but they are very noticeable for single glow points.

The greater stability of the negative corona may be explained in terms of the streamer theory of breakdown.[9] According to this theory, which seems to apply to divergent electric field conditions such as exist in the corona, spark breakdown occurs by formation of a streamer emanating from the anode. In the positive corona, the breakdown streamer thus starts from the wire in a naturally high field region and sparking occurs at relatively low voltage. In the negative corona, on the other hand, the streamer must start from the relatively low field region near the cylinder, and breakdown therefore requires a much higher voltage than in the case of the positive corona. In electric precipitators, the difference in sparking voltage between negative and positive corona may be as high as two or more.

VOLTAGE WAVEFORM EFFECTS

PURE D-C VOLTAGE is seldom used in energizing electric precipitators for industrial application because of the intensified sparking which it causes and the lower operating voltages necessary. With pure d-c voltage the spark discharge tends to develop into a sustained arc which with large precipitators is difficult to extinguish without opening circuit breakers. This, together with the fact that with pure direct current the voltage is at peak value 100 per cent of the time, makes it necessary in practice to operate at relatively lower voltages than are possible with intermittent unidirectional voltage waveforms such as those supplied by unfiltered rectifier sets. With the latter type of voltage wave, sparks in the precipitator are usually extinguished within 1 cycle because of the intermittent nature of the rectifier current flow, and electric operation is much steadier. Intermittent currents also permit operation of the precipitator at substantially higher peak voltages, and usually provide increased collection efficiency over that possible with pure direct current. For these reasons the intermittent waveforms are universally used for large electrostatic precipitators in the industrial field.

Both half-wave and full-wave rectification are used, the choice depending on the application and the precipitator size. Recently, high-voltage pulse generators somewhat similar to those used in radar have been used with success in electrical precipitation on an experimental basis. This introduces additional factors of flexibility in the duration and frequency of the current pulses and permits a substantial gain in operating voltage and collection efficiency over that possible with conventional rectifier equipment.

DISTURBANCES IN THE CORONA DISCHARGE

THE PRESENCE of the dispersoid particles may give rise to several disturbing effects which alter both the corona discharge and the precipitation phenomena. The most important of these effects are: 1. space-charge suppression of the corona current caused by the presence of charged suspended particles in the gas; and 2. the phenomenon of "back corona" which is caused by a layer of badly conducting dust on the collecting electrode surface.

In the discussion on the fundamentals of the corona it was brought out that the space-charge effect of the gas ions in effect adds resistance to the discharge path and reduces the corona current. It would be expected therefore that the space charge created by the presence of the charged suspended particles would further increase the resistance effect and reduce the corona current, and this is commonly observed. The effect is usually small with ordinary dusts, but may be very large with fine fumes and smokes because of the large concentration of particles present. The dispersoid space-charge density may easily attain values of 0.1 to 1 electrostatic unit per cubic centimeter, which is

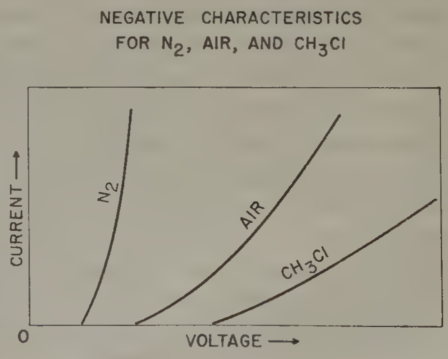

Figure 3. Variations in corona current-voltage characteristics encountered for several typical gases

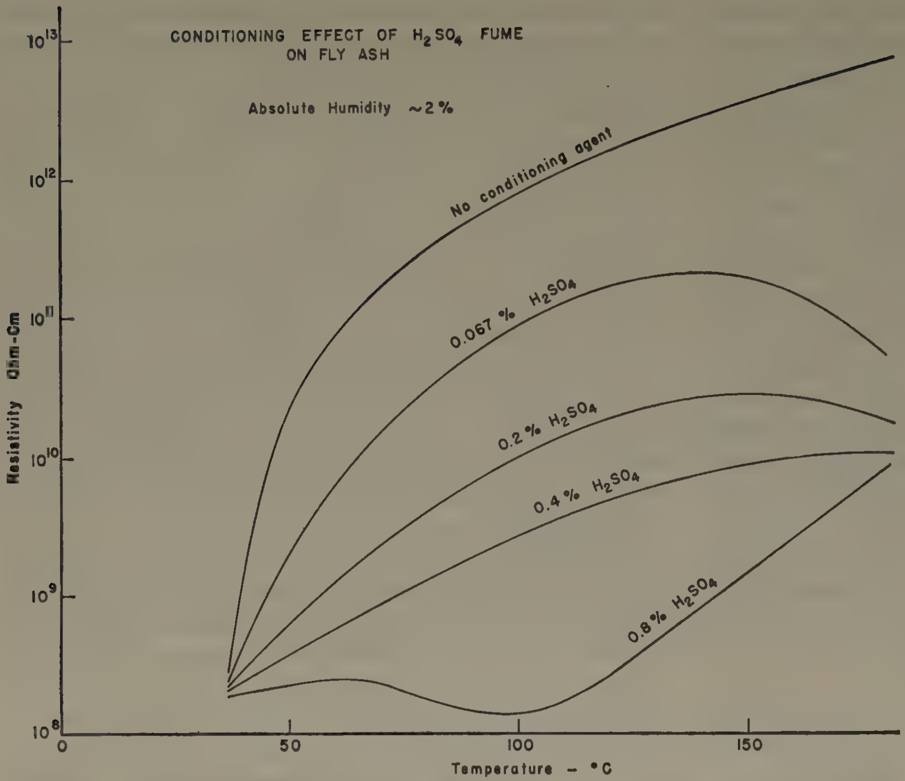

Figure 4. Conditioning effect of H_2SO_4 fume on fly ash. Absolute humidity approximately 2 per cent

of the order of magnitude of ion space-charge densities. The effect of added particle-space-charge fields of this magnitude is to further quench the corona current, in some cases to almost nil. However, for all except the most extreme particle-space-charge conditions, the current carried by the gas ions exceeds that carried by the particles by a factor of 100 to 1,000 or even more for light particle concentrations. The dust space-charge effect at times may prove troublesome in electrical precipitation practice, but presents no fundamental difficulty or limitation.

The exit gases from precipitators frequently carry a high electric charge. In some cases the charge may be accounted for by the presence of visible charged particles. But the condition also occurs even for highly cleaned gases containing only a few visible particles, so that the particle ions present must be submicroscopic in size. Ions of this type are well known in physics as Langevin ions. They have been detected in precipitator gases, but scientific information is at present meager. The effects of these charged precipitator gases are sometimes quite spectacular. For example, electric sparks up to several inches long sometimes may be drawn from an insulated sampling pipe inserted into the outlet flue of a precipitator.

It is of interest to note that charged particles are important in a number of fields in addition to electrical precipitation. Some of the industrial applications include spray painting, pile fabric manufacture, and an electric photographic process. The so-called precipitation static encountered in air flight appears to be due in part to clouds of charged water or snow particles and sometimes even dust particles. Of course the lightning discharge itself is a manifestation on a vast scale of space-charge fields produced by charged cloud or mist particles.

EFFECT OF PARTICLES ON THE ELECTRODES

Dust build-up on the collecting electrodes of 1/4 or 1/2 inch is normal in precipitator operation and usually has slight effect on the corona discharge. However, if the dust has very low conductivity, insufficient to pass satisfactorily the corona current to the underlying electrode a deleterious phenomenon known as "back corona" will occur. Back corona[10] is the descriptive term for the local discharge which occurs from the normally passive (collecting) electrode when it is covered with a layer of poorly conducting dust or fume. Onset of back corona is due to local electric breakdown of the dust or fume layer, caused by Ohm's law build-up of voltage, and usually occurs in electric precipitators when the bulk particle resistivity exceeds about 2×10^{10} ohm-centimeters. The initial stage of back corona is characterized by lowered sparking potential, while the more advanced stage, which occurs only when resistivity exceeds about 10^{11} ohm-centimeters, is characterized by formation of stable discharge craters in the dust layer, accompanied by a great increase in the corona current. In severe cases literally thousands of these craters per square foot of electrode surface may be seen. Severe back corona has been observed with dust layers as thin as 0.1 millimeter, while a dust layer approximately only one particle thick can reduce the corona sparking voltage by 50 per cent.

The initial or sparking stage of back corona lowers precipitator operating voltage and collection efficiency, but is not fundamentally serious. However, the advanced second stage of back corona may be very serious and may render a precipitator inoperative, chiefly because particles cannot be charged in the bipolar corona discharge which occurs under these conditions. The most practical method for overcoming back corona is to reduce the dust resistivity below the critical value of 2×10^{10} ohm-centimeters. This phase of the problem has been studied rather intensively with results which may be summarized briefly. It is found that dust and fume resistivities are strong functions of ambient temperature and humidity. Maximum resistivities usually occur at temperatures in the range of 100 to 150 degrees centigrade and at zero humidity. Values as high as 10^{15} ohm-centimeters are occasionally encountered in laboratory studies, but field values do not exceed 10^{12} to 10^{13} ohm-centimeters.

In practice, resistivity may be reduced by adjustment of gas temperature, by increasing the water vapor content of the gas, or by addition of slight traces of chemical compounds known as conditioning agents. Examples of conditioning agents are NH_3, SO_3, various chlorides, and certain oils. Conditioning agents are specific for each type of dust or fume. For example, NH_3 is highly effective with the aluminum silicate catalyst dust used in oil refining, but ineffective on the fly ash from pulverized-coal-fired boilers. At present, effective conditioning agents for new type of dusts are found largely by trial, as scientific data on dust conductivity are meager. An example of the variation of dust resistivity with temperature and of the strong effect of a conditioning agent is shown in Figure 4 for a sample of fly ash with SO_3 as conditioning agent.

PRECIPITATION EFFECTS OF THE CORONA[11]

Particle Charging. The first, and in many ways the most important, step of the electrical precipitation process is electric charging of the suspended particles. Although most of the aerosol particles of the atmosphere or in industrial gases are found to carry some electric charge, the magnitude of the natural charge is lower by a factor of ten or more than that which can be attained easily in the corona. Thus, even though particle collection by electric fields is usually possible without going through a preliminary electric charging process, such a method is unattractive as it requires unduly large equipment and is limited to rather low collection efficiencies.

The rate of collection of particles in a precipitator may be shown to be directly proportional to the particle charge. Doubling particle charge, for example, permits reducing precipitator size by a factor of two. The corona discharge, because of the copious generation of unipolar ions and because of the high electric fields possible, is the best practical means known for large-scale charging of suspended particles. Ion concentrations in the corona are typically 10^8 to 10^9 ions per cubic centimeter, or at least 1,000 times greater than the maximum particle concentration of any dispersoid. This, together with the relatively high velocities of the ions compared to dispersoid particles, means that under normal conditions all of the suspended particles are rapidly charged to a high degree in the corona field. Although free electrons undoubtedly can be effective in charging suspended particles, this mechanism appears to be relatively unimportant in electrostatic precipitation because the nature of the corona discharge ordinarily encountered is such that free electrons will be confined to the small active region close to the discharge electrode surface. Gases such as pure nitrogen in which there is no negative ion formation[12] are never encountered in practical applications.

Two partially independent particle-charging mechanisms occur in the corona, of which the most important is ion bombardment of the particles under the driving force of the applied electric field,[13, 14] and the less important, except in the case of very small particles below about 0.5-micron diameter, is diffusion of ions to the particles.[15] Theoretical calculations on the charging of spherical particles by the ion bombardment process lead to an equation of the form

$$n=\left(1+2\frac{D-1}{D+2}\right)\frac{E_0a^2}{e}\left(\frac{\pi N_0eKt}{\pi N_0eKt+1}\right)$$

where n=number of electronic charges on the particle; D=dielectric constant of the particle; E_0=magnitude of undistorted charging field in the neighborhood of the particle; a=particle radius; e=electronic charge; N_0= ion density in neighborhood of the particle; K=ion mobility; and t=time.

Table I. Theoretical Particle Charge for Conducting Spherical Particles

Charging Field, E_0 kv per centimeter	Particle Diameter, microns	Particle Charge, electrons
1	1	15
1	10	1,500
1	100	150,000
10	1	150
10	10	15,000
10	100	1,500,000

In this equation, the factor πN_0eK has the dimension of 1/time, so that it is convenient to define a time constant t_0 which is a measure of the rapidity of charging.

$$t_0=\frac{1}{\pi N_0eK}$$

Normally $t_0 \approx 10^{-3}$ second and charging is substantially complete in about 10^{-2} second. In like manner the time-independent factor represents the limiting or saturation charge n_s attained when $t>>t_0$.

$$n_s=\left(1+2\frac{D-1}{D+1}\right)\frac{E_0a^2}{e}$$

For a conducting particle it is clear that n_s is given simply by $3E_0a^2/e$.

Particle charge is seen to be proportional both to the strength of the charging field E_0 and to the surface area of the particle (represented by a^2). High charging fields obviously are desirable, and particle charge increases rapidly with particle size. Representative values of theoretical particle charge for the corona in normal atmospheric air are given in Table I. The theoretical particle-charging equation has been well confirmed by laboratory measurements. Particle-charge measurements for large precipitators are frequently in general agreement with theory, but large differences are common because of various disturbing effects which may occur.

Removal of the Charged Particles from the Gas. The second step of the electrostatic precipitation process, that of actual removal of the charged suspended particles from the gas stream to the passive or collecting electrode surface, is accomplished by the Coulomb force exerted on the particles by the electric field of the precipitator. Although a collecting field of the capacitor-plate type may be used, there are important advantages to be gained in using the space-charge field of the corona itself, and this is the usual arrangement for all heavy industrial precipitators. As previously mentioned, air-cleaning precipitators commonly use the capacitor-type collecting field, but the purpose in this case is to minimize ozone formation.

In practical precipitators the gas flow is always turbulent, both because of the gas velocities used and because of electric wind effects of the corona. Suspended particles

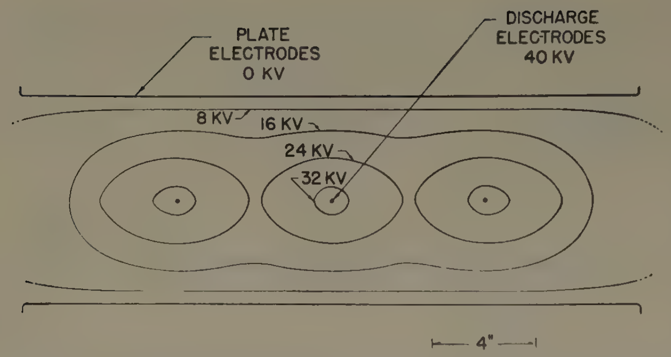

Figure 5. Equipotential lines between discharge and plate electrodes in duct-type precipitator. Note effect of space-charge in equalizing field

in a precipitator are subjected to the simultaneous influence of the turbulent gas motions and the Coulomb force which tends to drive the particles to the collecting electrode. However, the drift velocities of the charged particles in the field as determined by Stokes' law are usually of the order of magnitude of 1 foot per second or less, while the mean gas velocities generally used in precipitators are of the order of 10 feet per second, so that the gas flow and turbulence tends to control the motions and positions of the particles. As a result, the particles must be carried relatively close to the collecting electrode surface by the turbulent motion of the gas to be removed by the electric field. This factor to a large extent determines the electrode surface required. These general considerations lead to a statistical type expression for the collection efficiency η.[16]

$$\eta = 1 - \epsilon^{-\frac{A}{V} w}$$

where A = effective surface area of the collecting electrode; V = gas flow rate through precipitator; and w = drift velocity of the charged particles in the collector field.

The drift velocity w of a charged particle in the electric field of a precipitator is determined by the magnitude of the charge, the strength of the drift field, and the Stokes' law resistance of the gas. These factors combine to give the following equation, valid for spherical conducting particles

$$w = \frac{aE_0E_p}{2\pi\theta} \text{ (electrostatic and centimeter-gram-second units)}$$

where a = particle radius; E_0 = charging field; E_p = drift or precipitating field; and θ = gas viscosity.

The drift velocity is seen to be directly proportional to particle size a, so that large particles are collected at a faster rate than fine ones, but there is no theoretical lower limit to particle sizes which can be collected.

Efficient precipitation obviously requires that the collector field be made as high as possible, and it is here that the fundamental property of the corona discharge in providing a high space-charge field comes into play. Because of this effect, most of the lines of electric force leaving the collecting electrode surface terminate on the ionic charges throughout the space-charge region, and only a small proportion reach the wire. The net result is that the field near the collecting surface is enhanced greatly and particle collection is much more efficient than would be expected from the undistorted electrostatic field between the discharge and collecting electrodes.

It may be shown for wire and cylinder electrodes operating with appreciable corona current density that the electric field E near the cylinder wall is given by the approximate formula[17]

$$E \approx \sqrt{\frac{2i}{K}} \text{ (electrostatic units)}$$

where i = corona current per centimeter of wire; and K = ion mobility.

The formula shows that to obtain high fields the corona current should be made as large as possible and ions of low mobility should be used, although this latter factor is not usually subject to control.

For more complicated electrode systems such as coplanar wires and parallel plates (duct-type precipitators), even approximate calculations of the space-charge field become difficult and recourse is had to experimental measurements. Measurements of this type carried out in the writer's laboratory by a probe method are shown in graphical form in Figure 5. The field is seen to be much higher near the plate electrodes than would be the case if undistorted by the corona ions.

Role of Corona in Retaining Collected Particles. The third and final stage of the collection process is removal of the collected dust layers from the electrodes to a suitable hopper or other receiver. This final stage is of rather minor importance in air-cleaning precipitators or in very small installations, but is of major importance in large industrial precipitators which frequently collect 100 tons or more of dust per day. Actual removal of the collecting electrode dust deposits usually is accomplished by rapping the electrodes, which causes the dust to fall by gravity into the hoppers below.

This third stage is always limited by the tendency of the gas stream to blow dust off the collecting surfaces and to re-entrain dust as it drops from the electrodes during rapping. Just as the corona is vital to the particle charging and collecting phases of the process, it is important in this final stage, although in an indirect way. The importance results from the fact that most of the dust particles which are blown from the collecting electrodes by the gas stream or are re-entrained during rapping are recharged and reprecipitated immediately by the corona ions which are continually bombarding the deposited layer in large numbers. The losses from this cause therefore are reduced greatly permitting use of much higher gas velocities in the precipitator and insuring effective transfer of the collected dust to the hoppers without significant loss.

REFERENCES

1. The Precipitation of Smoke by Electrical Means, **Hohlfeld.** *Kastner Archiv Naturlehre*, volume II, 1824, pages 205–206.

2. **J. M. Gaugain.** *Annalis de Chemistrie et Physique* (Paris, France), volume 8, 1866, page 75.

3. Art of Separating Suspended Particles from Gaseous Bodies, **F. G. Cottrell.** United States Patent 895,729, 1908.

4. A New Electrostatic Precipitator, **G. W. Penney.** *Electrical Engineering*, volume 56, January 1937, pages 159–63.

5. Recent Developments in Analysis of the Mechanisms of Positive and Negative Coronas in Air, **L. B. Loeb.** *Journal of Applied Physics* (New York, N. Y.), volume 19, October 1948, pages 882–96.

6. Negative Wire Corona at High Temperature and Pressure, **L. R. Koller, H. A. Fremont.** *Journal of Applied Physics* (New York, N. Y.), volume 21, August 1950, page 741.

7. Investigations on the Physical Processes in Electrical Precipitation, **G. Mierdel, R. Seeliger.** *Archiv für Electrotechnik* (Berlin, Germany), volume 29, number 3, 1935, pages 149–72.

8. Dielectric Phenomena in High Voltage Engineering (book), **F. W. Peek, Jr.** McGraw-Hill Book Company, New York, N. Y., 1920.

9. The Mechanism of the Electric Spark (book), **L. B. Loeb, J. M. Meek.** Stanford University Press, Palo Alto, Calif., 1941.

10. Characteristics and Fundamentals of the "Back Corona" Discharge, **H. J. White.** Paper presented at the Gas Discharge Conference, Brookhaven National Laboratory, Upton, N. Y., October 27, 1948.

11. Electrostatic Collection of Fly Ash, **H. J. White, L. M. Roberts, C. W. Hedberg.** *Mechanical Engineering* (New York, N. Y.), volume 72, November 1950, pages 873–80.

12. Negative Coaxial Cylindrical Corona Discharges in Pure N_2, O_2, and Mixtures Thereof, **C. G. Miller, L. B. Loeb.** *Journal of Applied Physics* (New York, N. Y.), volume 22, number 5, May 1951, pages 614–21.

13. Method of Size Measurement for Suspended Particles, **H. Rohmann.** *Zeitschrift für Physik* (Berlin, Germany), volume 17, 1923, pages 253–65.

14. Charging of Spherical Particles in an Ionizing Field, **M. M. Pauthenier, M. Moreau-Hanot.** *Journal de Physique et Le Radium* (Paris, France), series 7, volume 3, 1932, pages 590–613.

15. The Mechanism of Charging of Mist Particles, **P. Arendt, H. Kallmann.** *Zeitschrift für Physik* (Berlin, Germany), volume 35, 1925, pages 421–41.

16. The exponential law of collection was discovered experimentally by **E. Anderson** in 1919 and is described, for example, in Perry's Chemical Engineers' Handbook, first edition, 1934, page 1548. A theoretical derivation of the equation was given by **W. Deutsch,** *Annalen der Physik* (Leipzig, Germany), volume 62, 1922, page 343, while the statistical basis of the formula has been established by the writer in reports which are as yet unpublished.

17. **J. S. Townsend.** *Philosophical Magazine* (London, England), volume 28, 1914, page 83.

Lightning Protection of Base Stations in the Mobile Radio Service

AIEE COMMITTEE REPORT

The lightning hazard to base station radio equipment can be minimized by a number of precautionary measures outlined in this report prepared by the Subcommittee on Mobile Radio. Protection of the antenna, transmission line, and station equipment are discussed.

THE OBJECTIVE OF this report is to indicate present-day engineering practice in the application of measures to minimize lightning troubles in base station radio equipment. The installations considered are the fixed or land stations, communicating with mobile units, and operating in the very-high-frequency band (30–300 megacycles).

The report supplements the lightning protection requirements of the National Electrical Code.[1] It is also supplementary to the applicable rules of the "Code for Protection Against Lightning" approved by the AIEE Standards Committee.[2] Additional information is based on suggestions submitted by members of the subcommittee and on installation practices followed by individual companies engaged in the manufacture and/or use of radio equipment in the mobile services.

In protecting a radio station against the effects of lightning, the fundamental problem is to provide sufficient conductivity or overvoltage protection to prevent the formation of disruptive potentials in station equipment, and to provide sufficient conductivity in the discharge path to by-pass the surge current directly to ground. Unless the added protective measures are adequate, damage may still occur in nonconductive elements from heat and mechanical forces generated by the discharge current. Even in metal parts where the effect of these forces is less, the mechanical strength and cross-sectional area of the metal must be sufficient to carry the surge current if damage is to be prevented.

The degree of protection required at a particular site is dependent upon the frequency and intensity of thunderstorms experienced in that section of the country, and upon the earth resistivity and grounding conditions.

Lightning protection required for a base station will also depend upon the height of the station structure relative to that of the surrounding buildings, trees, or other objects. Usually the height of the antenna tower will be such that the antenna will be exposed to more direct hits than would be experienced if the antennas were located somewhat lower than the surrounding objects. The lower antenna height, however, will be accompanied with a loss of station coverage. A primary objective in selecting a location for a radio station often is that the prospective site shall have sufficient height to provide a relatively unobstructed view of the surrounding area. To ensure satisfactory coverage, transmitting and receiving antennas are therefore mounted either on wooden or fabricated steel poles in rural areas, and on roof locations in cities where tall buildings are available.

Service interruptions may result from lightning strokes which produce dielectric or other circuit failures in com-

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Full text of a conference paper, "Lightning Protection of Base Stations in the Mobile Radio Service," recommended by the AIEE Committee on Radio Communications Systems and prepared by the Subcommittee on Mobile Radio. Scheduled for presentation at the AIEE Winter General Meeting, New York, N. Y., January 21–25, 1952. This report is published in advance of the meeting so that members may be prepared to discuss the subject.

Members of the Subcommittee on Mobile Radio are: A. C. Dickieson, *Chairman;* C. M. Backer; I. F. Byrnes; G. E. Dodrill; L. B. Grew; J. W. Kearney; L. P. Morris; J. E. Reid; C. E. Smith; and David Talley. S. K. Waldorf and V. A. Douglas made important contributions, as did also the remaining members of the AIEE Committee on Radio Communications Systems.

munication and power wire circuits connected to the station. The lightning voltages on these circuits may be high enough to require protective measures if permanent damage is to be prevented. The degree of protection required will vary with the physical size, type, and lightning exposure of the connected circuits.

PROTECTION OF THE ANTENNA

The structure of a base station antenna should have incorporated in it an arrangement which will prevent a lightning stroke from breaking down the dielectric material of the antenna and its associated transmission line. This protection normally takes the form of a gap between the whip (coaxial inner conductor) and the skirt (grounded outer conductor). A star gap often is used for this purpose. The term "star gap" results from the structural shape of the toothed washer, or star, employed as the inner ring of the gap. When the potential difference between points of the star and the antenna skirt exceeds some minimum value, the gap will break down to by-pass a large part of the lightning current to the coaxial outer conductor.

The star gap has the disadvantage that successive lightning strokes to the antenna will increase the spacing between the star gap points and the outer conductor and result in a gradual increase in the potential applied to the connected equipment. This action is a gradual one depending upon the frequency and severity of the strokes hitting the antenna. Inspection of the gap at intervals of 3 to 5 years may be desirable.

Where a star gap is not used in such an antenna, a short-circuited quarter-wave stub should be added in the transmission line immediately below the antenna or at the nearest point where the stub can be connected. The protection provided by the added short-circuited stub will be somewhat less effective than that obtained using a star gap.

It is desirable that the conductivity of the whip be in balance with other conductivities in the path to ground. In areas of severe lightning this may suggest a heavy-duty antenna. "J" and other antennas in which all exposed metallic parts are firmly grounded require neither star gaps nor stubs.

If there is no d-c path to ground through the radio equipment, near-by strokes may build up potentials between the inner and outer conductors of the coaxial line. A suitable resistor (20,000 ohms, 2 watts) connected between the two conductors will drain off the static charge and tend to reduce noise which is sometimes observed at radio receiver locations. The measure is not effective in the case of a direct lightning hit on the antenna.

PROTECTION OF THE TRANSMISSION LINE

With any of the arrangements outlined here, a lightning stroke to the antenna will result in a heavy flow of current on the outer conductor of a coaxial transmission line. In a solid dielectric coaxial line, the dielectric may be damaged by the generation of heat. In an air dielectric line, the outer conductor may be collapsed to short-circuit the inner conductor by the mechanical forces set up by the surge current. The protective practice is to add conductivity in parallel with the outer conductor so as to reduce the proportion of surge current carried by the coaxial line.

On metal poles or towers, the additional conductivity is provided by bonding the outer conductor of the coaxial line to the metal at the antenna and also at the point where the transmission line leaves the structure. If in addition to these bonds the coaxial line is run inside the tower structure, the current carried on the line will be reduced.

On a wooden pole, a number-6 copper wire, or equivalent, should be run between the top and bottom of the pole on the side away from the transmission line. U-shaped cable-guard sections often are used to cover the transmission line throughout its vertical length for mechanical protection. At the top of the pole, the vertical paralleling wire should be connected to the outer conductor of the coaxial line and to the U-guard section. Where the transmission line leaves the pole, the paralleling wire should also be connected to the outer conductor of the coaxial line and to the U-guard. The auxiliary conductor should be extended to ground level and interconnected there with the station ground system. If the radio equipment is mounted on the same pole, the outer conductor of the transmission line is connected to the equipment ground along with the auxiliary wire and U-guard. This construction usually will take care of an isolated antenna installation on a wooden pole.

Where the antenna is mounted on a mast beside a building in which the base station equipment is housed, grounding arrangements specified by the National Electrical Code[1] and the Code for Protection Against Lightning[2] should be followed. It may be found that the ground to which the equipment is connected is materially lower in resistance than the made ground at the foot of the mast. When this condition obtains, if the antenna is struck by lightning, a considerable portion of the surge current will be diverted via the transmission line to building ground. To prevent crushing, an aerial transmission line between the mast and the equipment housed inside the building should be enclosed in metal conduit. At the mast, the conduit should be bonded either to the ground lead or to the mast itself if it is metal. Inside the building the conduit should be bonded to the building ground and to the outer conductor of the transmission line. Where the coaxial lead is run in underground conduit from the mast to the building, the outer conductor of the coaxial lead should be grounded at the base of the mast and also within the building.

It should be noted that application of any considerable heat in soldering to the outer conductor of a solid dielectric transmission line may damage the coaxial line. Where a bond to the coaxial outer conductor is required, the following method may be used without damage to the dielectric: remove 4 to 5 inches of the vinyl covering of the outer conductor. Lash the bond or grounding conductor firmly to the outer coaxial surface using tinned copper lashing wire. When completed, the bond should be covered appropriately as a protection against the elements.

If the mast is located within six feet of the building, a lightning stroke to the antenna may arc from the mast or coaxial line to any ungrounded metal mass such as a roof or stack which is near-by, or to grounded metal such as conduits and plumbing. It is usually advisable in such cases to bond the metal part of the mast to the metal parts of the building. Small ungrounded metal surfaces need not be bonded.

Where a metal mast is mounted on a building, the mast should be bonded to the building steel as required in the National Electrical Code.[1] If the mast is wood, the auxiliary wire and U-guard combination discussed here should be bonded to building steel. If the building does not have a steel structure, a grounding cable of relatively large cross section should be used to carry the lightning current to earth by the most direct route. A number-2 copper conductor, or equivalent, should be used for this purpose. Grounding to near-by pipes of a steam or hot water system is not recommended as a general practice. With such a connection to a small pipe or conduit, the threaded joints may be burned by a lightning stroke and their usefulness impaired.

Where a mast is guyed with wire cables, the guys should be connected to the building steel. Where a wooden antenna mast is employed, the guys should be bonded to the transmission-line outer conductor, to the auxiliary wire, and to the U-guard where the guys contact the pole.

PROTECTION OF MARKER LIGHTS

WHERE MASTS ARE equipped with marker (aircraft warning) lights fed by 110- or 220-volt power circuits, the neutral of the power circuits and conduit, if provided, should be bonded to other grounded parts at the top of the mast. The metal cap of the top tower lamp fixture should be connected to tower ground if the connection is not made through the lamp housing. If the lamp housing is grounded through threaded conduit joints, the threads may be damaged by surge currents. Another possibility is to arrange a U-shaped metallic shield over the fixture, with the shield bonded to the tower structure.

This arrangement is usually sufficient to guard against damage occurring as a result of lightning surges in the antenna structure. Lamp failure as a result of lightning surges in power distribution lines connected to the base station equipment is discussed in the next section.

PROTECTION OF STATION EQUIPMENT

LIGHTNING PRODUCES surge currents of thousands of amperes. If the ground resistance is even a few ohms, the potential of the site will be raised by thousands of volts with respect to remote earth. This may make little difference within the station if all of the metal parts are connected to a common ground. In the usual case, however, the power and telephone lines entering the station are perforce connected to other grounds at remote points; the difference in ground potentials caused by the surge current must be dealt with.

The radio station thus acts as a source which introduces surges into the power and telephone networks. Likewise, the power and telephone lines may conduct into the radio station the effects of surges caused by lightning strokes some distance away. The problem requires joint consideration by the engineers concerned with the protection of the radio station, the power lines, and the telephone lines.

It is considered good practice to provide a station ground bus to facilitate the common grounding of such things as the lightning arresters on the power and communication circuits, the outer conductors of coaxial lines, conduit, equipment cases, gas and oil pipes, plumbing, and metallic members of the building structure. Connection to the power system primary ground should be discussed with the local power people to be sure that it does not produce an undesirable fault current condition. Usually, lightning protection for the radio station is improved by connecting primary and secondary grounds (either solidly or by suitable air gaps) and by connecting the primary lightning-arrester ground leads (solidly or by suitable air gaps) to the power secondary ground.

Interconnecting the grounds reduces the total ground resistance, and hence the voltage associated with a given surge current. The division of currents among the grounds will depend on their relative impedances. The most desirable situation exists when the radio station ground is good enough so that the major portion of the surge current is conducted to earth locally.

This requires a station ground resistance of less than 10 ohms, which may be better than is required solely for radio transmission reasons. In certain types of terrain, such a ground may be difficult or expensive to achieve. The problem should be considered jointly by all agencies involved, so as to protect continuity of service.

In cities and large towns, where the antennas are located on tall buildings, and properly grounded to the building structure, the metal frame provides a good path for the lightning current to flow to ground. The over-all problem is somewhat simpler than in the case of an isolated station located on a high mountain.

To protect base station equipment against surges brought into the station over the power lines, low-voltage protection should be applied to the secondary distribution power circuits. One form of this low-voltage protection is obtained by bridging a Western Electric *D-159235* silicon carbide varistor (or equivalent) in series with 700-volt protector blocks (0.006-inch gap) across the 110-volt power circuit feeding the radio equipment. This protective equipment should be mounted in the radio cabinet. On branch circuits equipped with varistor protectors, slow-blow fuses or circuit breakers should be used instead of standard fuses.

To reduce protector block operation, and prevent flashover of the varistor for heavy strokes, a General Electric *9LA15A4* or a Westinghouse type *AO* protector is connected across the secondary at the service entrance. This low-voltage protection is also helpful in reducing lightning damage to aircraft warning lights on antenna towers. Another protective measure which may be helpful in some instances is to bond the neutral of the a-c power supply secondary circuit to the metal wall inside the radio cabinet.

REFERENCES

1. National Electrical Code. *Pamphlet number 70*, National Board of Fire Underwriters (New York, N. Y.), 1951.

2. Code for Protection Against Lightning. *Handbook H40*, National Bureau of Standards (Washington, D. C.); *NFPA number 78*, National Fire Protection Association (Boston, Mass.); *ASAC5*, American Standards Association (New York, N. Y.), 1945.

Servo Characteristics of a Rectifier-Driven Motor

L. D. HARRIS
MEMBER AIEE

THERE ARE A significant number of applications of d-c motors in which either the armature power, field excitation, or both, are supplied by one or more controlled rectifiers. In one type of servomechanism system, the speed of the motor is controlled through the armature power by a controlled rectifier; in another type, the motor speed is controlled by the action of a controlled rectifier upon the field excitation. Previous papers[1,2] have been written wherein an analysis is made of the case where the armature power is supplied by a controlled rectifier under steady-state conditions. To the engineer interested in employing the d-c motor and controlled-rectifier combination as a prime mover in a closed-loop control system, the steady-state analysis is significant but not necessarily sufficient.

When a full-wave, single-phase, grid-controlled rectifier supplies the armature power of a d-c motor, the differential equation involving the armature current i can be written as

$$e=E_m \sin(\omega t+\beta)=L_a\frac{di}{dt}+iR_a+E_b \tag{1}$$

where β is the angle at which the tube is allowed to break down, R_a and L_a are resistance and inductance respectively of the closed circuit through the armature of the motor, and E_b is sum of the tube drop and generated voltage of motor. When the proper manipulations are made of this equation for the case where the armature current flow comes in pulses rather than continuous flow, equations 2 and 3 are developed.

$$S_f=\frac{E_b}{E_m}=\cos\theta_a\left[\frac{\sin(\beta+\theta_a+\gamma)-\epsilon^{-\gamma/\Gamma a}\sin(\beta+\theta_a)}{1-\epsilon^{-\gamma/\Gamma a}}\right] \tag{2}$$

$$T_f=\frac{I_aR_a\pi}{E_m}=\cos\beta-\cos(\beta+\gamma)-S_f\gamma \tag{3}$$

where $\theta_a=-\tan^{-1}\omega L_a/R_a$, $\Gamma_a=\omega L_a/R_a$, and γ is the angle at which the armature current in any pulse returns to zero. The actual speed of the motor is measured through the speed factor S_f. Through equations 2 and 3, one may compute a family of curves relating the speed of the motor to the average armature current I_a.

When this d-c motor and rectifier combination is employed in a speed servo system, the dynamic operation of the combination about a given operating point is given by the transfer function of equation 4.

$$\frac{\mathbf{S}}{\boldsymbol{\beta}}=\frac{\partial T/\partial\beta}{\dfrac{\partial T_L}{\partial S}-\dfrac{\partial T}{\partial S}+j\omega J} \tag{4}$$

where $\mathbf{S}$ and $\boldsymbol{\beta}$ are sinusoidal complex values of the motor speed and control angle respectively, T is the developed torque, and T_L is the torque required by the load. The partial derivatives, $\partial T/\partial\beta$ and $\partial T/\partial S$, can be evaluated in terms of equations 2 and 3, and $\partial T_L/\partial S$ is fixed by the nature of the load. When the armature current flow is in discrete pulses, the armature inductance does not give a significant delay to the average value of the armature current. For this reason, only one significant delay term, J (the inertia of the rotating system), appears in equation 4.

When motor speed control is achieved by supplying the field excitation through a controlled rectifier and the field current flow is continuous in nature (continuous flow is the more usual for the field circuit), the dynamic response of the average value of the field current, I_f, in respect to the driving force, β, is given approximately by the following equation

$$\frac{2E_m\cos\beta}{\pi}-E_t=L_f\frac{dI_f}{dt}+R_fI_f \tag{5}$$

Where the control angle is controlled by a d-c grid signal, E_c, which is superimposed upon a quadrature a-c signal, a significant transfer function in the frequency domain is given by equation 6.

$$\frac{\mathbf{I}}{\mathbf{E}_c}=\frac{2E_m}{\pi E_{mg}(R_f+j\omega L_f)} \tag{6}$$

where E_{mg} is the maximum value of the a-c component of the grid signal. In equations 5 and 6 one sees a delaying effect of the inductance of the field upon the average value of the field current because the flow of current is continuous from one pulse to another. When the transfer function between the field current and the motor speed is used to eliminate the field current term from equation 6, equation 7 results.

$$\frac{\mathbf{S}}{\mathbf{E}_c}=\frac{2E_m\left[R_a\dfrac{\partial T}{\partial I_f}-\dfrac{\partial T}{\partial I_a}\dfrac{\partial E_g}{\partial I_f}+j\omega L_a\dfrac{\partial T}{\partial I_f}\right]}{\pi E_{mg}(R_f+j\omega L_f)\left[\left(\dfrac{\partial T_L}{\partial S}+j\omega J\right)(R_a+j\omega L_a)+\dfrac{\partial T}{\partial I_a}\dfrac{\partial E_g}{\partial S}\right]} \tag{7}$$

Equation 7 was developed assuming that the various parameters such as $\partial T/\partial I_f$, $\partial T/\partial I_a$, $\partial T_L/\partial S$, L_a, and so forth, are independent of the variables I_a, I_f, and S. This assumption is not justifiable except when the range of variation in these variables is sufficiently small; therefore, equation 7 should be considered as the small-signal transfer function and is a significant guide to the problem of synthesizing a servo system using the d-c motor with controlled excitation to achieve speed control.

REFERENCES

1. Theory of Rectifier—D-C Motor Drive, **E. H. Vedder, K. P. Puchlowski.** AIEE *Transactions*, volume 62, 1943, pages 863–70.

2. Voltage and Current Relations for Controlled Rectification with Inductive and Generative Loads, **K. P. Puchlowski.** AIEE *Transactions*, volume 64, 1945, pages 255–60.

Digest of paper 51-297, "Servomechanism Characteristics of D-C Motor Driven by Controlled Rectifiers," recommended by the AIEE Committee on Feedback Control Systems, and approved by the AIEE Technical Program Committee for presentation at the AIEE Pacific General Meeting, Portland, Oreg., August 20–23, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

L. D. Harris is with the University of Utah, Salt Lake City, Utah.

The Failure of Overhead Ground Wires Caused by Aeolian Vibration

P. G. WALLACE
MEMBER AIEE

Vibration fatigue is a hazard to overhead transmission lines. A comparison is made in this article of several types of overhead ground wire construction and the methods used to avoid damage caused by vibration fatigue.

RECENTLY THE PROBLEM of damage caused by aeolian vibration has become a matter of more than usual concern to many engineers responsible for the design, construction, and maintenance of overhead lines. This article proposes to compare the results of various types of construction used to install overhead ground wires and call attention to some of the more common methods of avoiding damage caused by vibration fatigue.

It was not until 1925 that vibration was identified as the cause of failure of an overhead line; from that time until 1932 a great deal of trouble was experienced, and at the same time several manufacturers and power companies carried on intensive research programs to determine the best way to eliminate or mitigate the adverse results of vibration. These efforts brought about several damping devices and better clamp designs, together with a clarification of the relationships of wind and tension to mechanical fatigue in overhead wires. The power companies have profitably taken advantage of these results, and very few overhead ground wire failures have been caused by aeolian vibration since 1932.

Originally, overhead ground wires usually were installed with the same sag as the conductors, resulting in operating tensions that were low compared with the strength of the cable. Later as the function of the shield wire became more clearly understood, it was realized that better protection would be obtained by increasing the vertical separation between the overhead ground and the phase conductors; economical construction practices dictated that this be done by increasing the tension in the shield cable as much as ice loading would permit. As a result, many overhead ground cables were operating at 35 per cent of rated breaking strength at 60 degrees Fahrenheit. A pronounced example of the results of this type of construction occurred in Texas in 1931.

On this particular line, two 3/8-inch high-strength 7-strand steel cables were used. The average span was 600 feet, and the cable was sagged to withstand heavy loading conditions at 60 per cent ultimate strength. The 60-degree Fahrenheit tension was 3,770 pounds, or 34.9 per cent of ultimate strength. The shield wire was supported by means of suspension clamps which were attached in such a way as to permit no motion other than rocking in the vertical plane, see Figure 1. No damping devices were used. Severe vibrations were noted soon after installation, and measurements were made as to their amplitude and frequency. The measurements indicated vibration amplitudes of 0.1 to 0.4 inch and frequencies up to 110 cycles per second. Broken strands in the cables first appeared after only 5 months of service, and after 9 months damaged strands were found at 25 per cent of the points of support. This case is an illustration of the rapidity with which vibration fatigue may develop when conditions are favorable.

The cables were repaired and resagged in the summer of 1932. The new sag was calculated on the basis of 4,500 pounds tension under heavy loading conditions, which reduced the normal operating tension from 3,770 pounds to 1,400 pounds. A few dampers had been installed before the repair work and these were placed back on the line after the resagging was completed. No trouble has been caused by vibration on this line since the completion of repairs.

Figure 2 shows five charts which were made with a high-speed recorder while this line was vibrating so seriously. These charts illustrate the complexities of theoretical investigation in the field of aeolian vibration. Upon examination, they disclose only vague and seemingly contradictory relationships between wind velocity and amplitude and frequency of vibration.

A similar experience occurred on a line in Southern

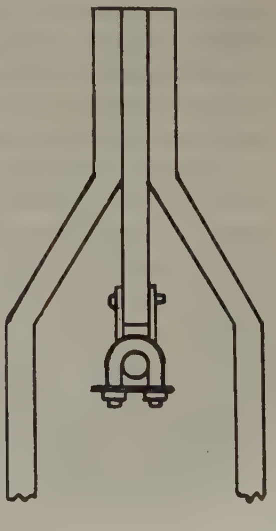

Figure 1. Suspension clamp for shield wire which permits no motion other than rocking in the vertical plane

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Full text of a conference paper, "Failures of Overhead Ground Wires Caused by Aeolian Vibration," recommended by the AIEE Committee on Transmission and Distribution and presented at the AIEE Fall General Meeting, Oklahoma City, Okla., October 23–27, 1950.

P. G. Wallace is with the Texas Power and Light Company, Dallas, Tex.

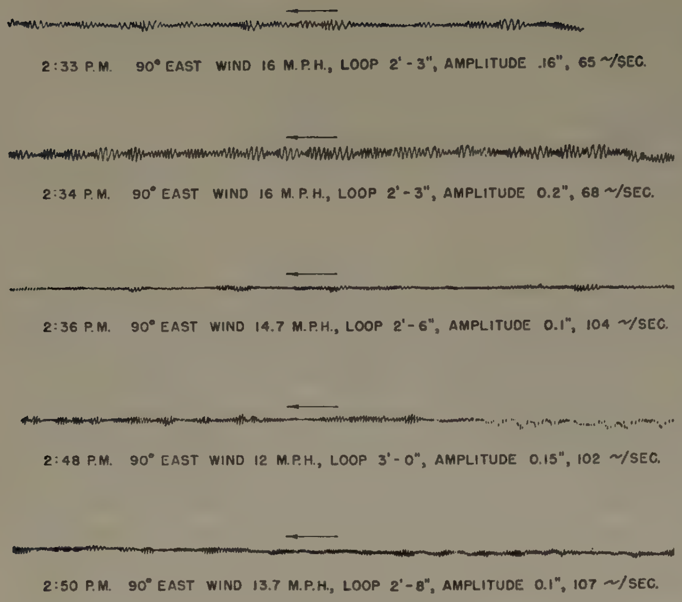


Figure 2. Vibration charts for 3/8-inch high-strength steel shield wire

650-foot span; 3.8-foot sag; 3,770-pound tension; 3.25-inch per second recorder speed

California. This line uses a 1/2-inch high-strength galvanized steel cable as its overhead ground, which is supported with a rigid clamp. The cable was installed with a 60-degree Fahrenheit tension of 6,580 pounds, or 35 per cent of rated strength. Broken strands were found after a very short period of operation.

The following construction practice used by a utility in North Texas has proved satisfactory. This company uses 3/8-inch extra-high-strength 7-strand galvanized steel cable for its overhead ground. The cable is supported with a suspension clamp which is attached to the tower by means of a U-bolt and a chain link. See Figure 3. The cable was prestretched to 4,500 pounds and installed with a 60-degree Fahrenheit tension of 2,060 pounds or 14 per cent of ultimate strength; the tension under heavy loading conditions is 4,000 lbs. Some of the lines built by this company have been in service over 13 years, without any indication of damage from vibration.

Several lines now in service use a rigid clamp as the shield wire support, Figure 4. The cables are either 3/8- or 5/16-inch steel. The tensions used are in the order of 1,000 pounds, or less, which are much lower than those normally used with the same cables. Some of these lines have been in service over 30 years, and have experienced no vibration difficulties. As an illustration of the role of tension, a line in Central Texas may be compared with those last mentioned. The shield on this line is 3/8-inch high-strength steel cable supported by a semirigid type clamp, see Figure 5. The cable was installed with a tension of 1,950 pounds, or 18 per cent of rated breaking strength. After 4 years of service, broken strands were found in several clamps. The tension was reduced to 1,350 pounds, and there has been no evidence of further trouble for 7 years.

These cases supply a fair cross section of the structural conditions believed to contribute to aeolian vibration failures in galvanized steel shield wire. While these cases present insufficient data to be used in drawing definite conclusions, they do indicate guide posts towards safe construction practices.

Lines using inflexible supports provide a very dangerous condition with respect to vibration fatigue. In the absence of damping devices, tensions used on cables so supported should be maintained at a small percentage of rated breaking strength to avoid damage completely. The cases mentioned indicate that 35-per cent tension is likely to lead to rapid failure, and that 20 per cent may lead to eventual damage. The only lines cited in this category that have been completely free from vibration fatigue for a conclusive period of time are those using 10-per cent ultimate strength, or less, as the normal operating tension. This tension probably does not take complete advantage of the cables, inherent antivibratory qualities, and may be increased a small amount; however, it is felt that the tension should not be raised above 15 per cent without providing some means of relieving the stress at the point of support.

Lines employing semiflexible supports for the overhead ground wire do not show signs of vibration fatigue when installed with a normal tension of 15-per cent rated breaking strength; however, when the tension is raised to 35 per cent, the indications are that damage occurs approximately as quickly as when rigid supports are used. It may be that the small flexibility provided in this type of support is insufficient to allow the clamp to move with the conductor and thereby reduce the bending stresses at the clamp below the danger point.

The choice of reasonable operating tensions and the use of mobile suspension clamps has proved to be the best way to protect overhead ground wires from aeolian vibration damage.[1] Lower operating tensions can be obtained in the initial period of installation by prestretching the cables. In a recently built line (December 1949), the 7/16-inch extra-high-strength steel shield wires were prestretched to 12,000 pounds, and installed at 3,210 pounds, using preformed armor rods and suspension clamps. Present indications are that this line will give exceptionally long life and reliable service.

The use of armor rods as a damping and protective device is becoming more widely accepted. These have a great advantage in vibration protection since they both protect the cable at the point of vibration damage and damp the vibrations as they approach the cable support. Laboratory tests show that the life expectancy of a cable would be greater if installed at 25 per cent of ultimate strength with armor rods than if installed at 15 per cent of ultimate

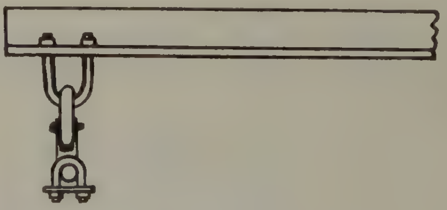


Figure 3. U-bolt and chain link arrangement for supporting cable

strength without armor rods. Preformed armor rods are relatively new, and have met with some objections when installed on aluminum; however, the hardness of the steel strands matches that of the preformed rods and the objectionable features thereby are relieved. One of the first lines employing preformed armor rods on the shield wire was built in the latter part of 1946 between Jewett and Lufkin, Tex. The shield wire is 3/8-inch high-strength steel, installed with an initial tension of 1,780 pounds. Observations to date have revealed no signs of abrasion. Laboratory tests indicate preformed rods have approximately the same vibration protection advantages as straight armor rods.

There is a possibility that the tension recommendations in rule *261 F4* of the National Electrical Safety Code are too high. This rule recommends that the final tension at 60 degrees Fahrenheit should not exceed 25 per cent of the breaking strength, and this recommendation is followed by most wire manufacturers when calculating the sag and tension tables for their product. However, the Aluminum Company of America uses the limitation of final tension not to exceed 25 per cent of the breaking strength at 0 degree Fahrenheit. An interesting comparison of these limitations may be made using a 500-foot span of 3/8-inch high-strength steel as an example. If the cable is installed on the basis of the Code recommendation, the 0-degree Fahrenheit tension is 3,400 pounds, or 31 per cent of the cable breaking strength, or 6 per cent more than the Aluminum Company results. In areas subject to 0-degree Fahrenheit temperatures, this factor may be the difference between a permanent installation and one requiring regular repairs.

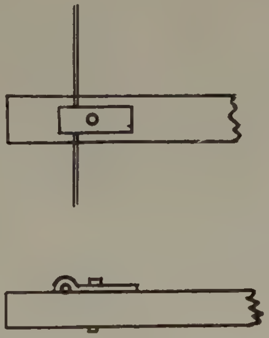
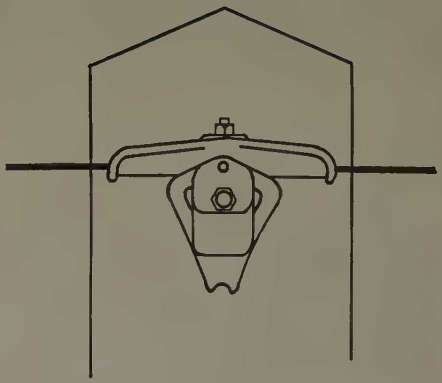


Figure 4. Rigid clamp for shield wire support

The triangular shape of 3-strand cables offers certain desirable vibration characteristics. Experience shows that this shape cable will vibrate destructively when the proper combination of forces is applied, which is true for any elastic system suspended in tension; however, 3-strand cables will vibrate for a shorter period of time than a cable of circular shape when both are subjected to the same vibration producing conditions.[2] This indicates that a longer life may be expected from a 3-strand cable when it is subjected to conditions that tend to create destructive vibrations; however, by no means should it be considered a cure-all of vibration troubles.

The high cost of copperweld in relation to comparable galvanized steel cables has retarded its widespread acceptance as an overhead ground conductor; however, some companies have found that the higher corrosion resistance and conductivity offset the cost differential when applied to their particular conditions. Experience with copperweld indicates that approximately the same vibration performance may be expected from it as from galvanized steel.

Figure 5. Semirigid type clamp used for supporting shield wire



Other considerations related to vibration failures are damages to the supporting structure and its appurtenances. Bayonet and tower arm failures have been attributed to vibration of their attached cables; these failures appear in the form of cracks at bolt holes, and usually are found on long tension members and on long bayonets. These difficulties have been solved by the use of intermediate bracing and installation of damping devices. Copper-pole ground wires connected directly to the overhead ground are subject to the same vibrations as the cable itself, and usually will break much more quickly than the cable. The most obvious solution to this is to attach the pole ground to a rigid point on the shield wire support; copperweld or steel-pole ground wires will remain intact longer than copper, but they are subject to the same failure. Wood H-frame lines using two shield wires often have overhead wire ties suspended between the supporting bayonets. These ties have been known to fail on one side and drop into the phase wires. A more rugged and less dangerous tie may be made by using a single angle iron crossarm bolted to the top of the poles which will serve as both a support and tie; this method lends itself readily to the installation of a flexible clamping system.

The basic problem confronting the engineer today is getting the most protection from the overhead ground wire for each dollar spent on its installation; this problem is resolved into obtaining the economical balance between a reasonable tension in the shield wire and additional height of the structure, with due consideration being given to the various factors influencing the life of the installation. The use of refinements such as armor rods and flexible clamps will permit higher tension without endangering the life of the cable; both of these refinements are relatively inexpensive, particularly when compared with the structure height savings they permit.

REFERENCES

1. Vibrations of Small Amplitude. International Conference on Large Electric High-Tension Systems (Paris, France), International Study Committee Number 6, 1950, page 201.

2. Conductor Vibration, L. C. Peskin. Paper presented before Edison Electric Institute, Chicago, Ill., May 4, 1939.

A Study of Sampled-Data Control Systems

W. K. LINVILL

AN ANALYSIS OF sampled-data servomechanisms which is useful in system design is described in this article. A sampled-data system has a sampling device at some point in the transmission. A sampling device has an output which is related only to input samples which are taken at instants equally spaced in time. If $\Theta_i(t)$ be the input signal to the device, then the output is related in a linear fashion to $\Theta_i(nT)$, where n is any integer and the constant T is the length of time between samples. When the sampling device is put in the feed-forward section of a servomechanism, special stability problems arise which are not present in the conventional servomechanism with continuously supplied error data.

Linear difference equations have been used to analyze sampled-data systems. While this procedure is correct, it is cumbersome to use because it does not give system-response characteristics directly in terms of element characteristics and therefore is useful only to determine whether or not a given system is stable.

The essential contribution of this article to the analysis and design of a sampled-data system arises from the recognition that the sampling device is additive; that is, its responses to separate inputs are superposable. Furthermore, most of the components in a sampled-data control system are conventional, operate on continuous signals, and can be described most conveniently by conventional frequency analysis. Whereas others have described the whole system (both sampled and continuous-data parts) in terms of sampled data, this article describes the whole system in terms of continuous data. To do this, the response of the sampling device to a continuous signal must be obtained.

Response characteristics of a sampling device are determined by describing the response at the output of the sampling device when the input is excited by a single exponential of complex frequency s. The describing function is analogous to the usual type of transfer function which is used to describe conventional linear systems. The essential difference between the sampling device and a conventional linear device is that when one applies a single exponential excitation to the usual linear device, the resulting output is also a single exponential; this is not true of a sampling device. When one applies a single exponential to the sampling device, the resulting output is a whole family of exponentials whose complex frequencies are separated by the radian-per-second equivalent of the sampling frequency, $1/T$. The describing function of the linear device, usually called a transfer function, relates the single exponential output component to the single exponential input component. The describing function of the sampling device, not a transfer function, relates the family of exponentials at the output of the sampling device to the single exponential input.

The properties of the sampling device are characterized most simply in terms of an equivalent circuit which has the same describing function as the sampling device. The equivalent circuit is an impulse modulator. The impulse modulator supplies the additional frequencies associated with the process of sampling. The only unconventional element in a sampled-data system is the impulse modulator, and its characteristics are very simple to describe in terms of Laplace transforms. If the Laplace transform of the input to the impulse modulator is $\Theta_i(s)$ then the Laplace transform of the output from the impulse modulator is

$$\sum_{n=-\infty}^{\infty} \Theta_i(s+jn\Omega)$$

where Ω is the radian-per-second equivalent of the sampling frequency and n has all integer values and zero. The fact that the remainder of the system has negligible response to the higher frequency components means that the only effective elements of the impulse modulator output are those which have small n-values.

Using the equivalent circuit of the sampling device methods are developed for analyzing sampled-error-data control systems. The analysis developed gives the output continuously in time in terms of the continuous input. The relation between the output and input transforms is given directly in terms of element transfer functions and simple sums of them.

The performance of a sampled-error-data control system can be evaluated from a study of the following:

1. The faithfulness with which the output signal follows the input signal as indicated by the system function.
2. The degree of stability of the system as indicated by location of poles of the system function.
3. The amount of ripple in the output arising as a result of sampling as indicated by the frequency characteristics of the feed-forward section of the system.
4. The quality of output monitoring accomplished by sampled feedback as indicated by a study of the system function.

Thus, all the significant performance characteristics of sampled-data systems can be studied in the frequency domain just as similar performance characteristics of conventional control systems are studied. Accordingly changes in the system elements can be correlated with performance changes for sampled-data systems the same as is done for conventional systems, and conventional design techniques can now apply to sampled-data systems.

Digest of paper **51-324**, "Sampled-Data Control Systems Studied Through Comparison of Sampling with Amplitude Modulation," recommended by the AIEE Committee on Feedback Control Systems and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

W. K. Linvill is with Massachusetts Institute of Technology, Cambridge, Mass.

Economic Comparison of Energy Differences

A. P. FUGILL
MEMBER AIEE

OTHER PAPERS TREAT the various factors involved in comparing the cost of two or more means of accomplishing a desired result in the planning of an electric power system. This article determines the amount of energy involved in the different schemes being compared, and the money value of that energy. The fundamental principle is to determine for each scheme, as accurately as possible, the actual cost of the losses which will accrue during the life of the facility.

As an example of the procedure, assume that a new power plant is to be added to a system at one of two possible locations and it is necessary to evaluate the difference in losses due to location. The annual load duration curve for the system is given in Figure 1(*A*) and the envelope of daily load curves in Figure 1(*B*).

The first step is to determine the loss duration curve of Figure 1(*C*), which gives the difference in system loss for the two locations of plant. If loss were solely a function of load magnitude, the system loss for each plant location could be determined for each load of Figure 1(*A*) from a knowledge of the current division and resistance of the branches in the system network. Since system loss is also a function of load distribution and power factor, which vary with the time of day and the season of the year, the daily load curves of Figure 1(*B*) are needed to estimate when the loads of a given magnitude occur. In this case, the day is divided into three periods—night, day, and evening. Within any one period, the load distribution, the load power factor, and the loss are essentially constant for each load. From known values of loss for these three periods, a weighted average loss is obtained for each load, based on the proportionate amount of load which occurs in each time period.

For example, since load *A* of Figure 1(*A*) occurs twice as often in the day period as in the evening period, as indicated by *AA'* in Figure 1(*B*), the loss to be used for load *A* is one-third the sum of twice the day loss plus the evening loss. Following this procedure, the loss for load *A* and for other loads is calculated for each plant location and the difference used to plot the curve of Figure 1(*C*). The integration of the area under the curve is the total annual energy differential between the two locations.

The cost for this energy is not the cost of generation at the new plant, but the increment cost of generation on the system, which is usually a function of load magnitude only. With the increment cost on the particular system known for different system loads, the cost per hour for the differential loss is plotted in Figure 1(*D*) on the assumption that the unit cost of the loss at *A* in Figure 1(*C*) is the increment cost of energy on the system for a load of magnitude *A* in Figure 1(*A*). The integration of the area under this curve is the total annual differential cost of energy.

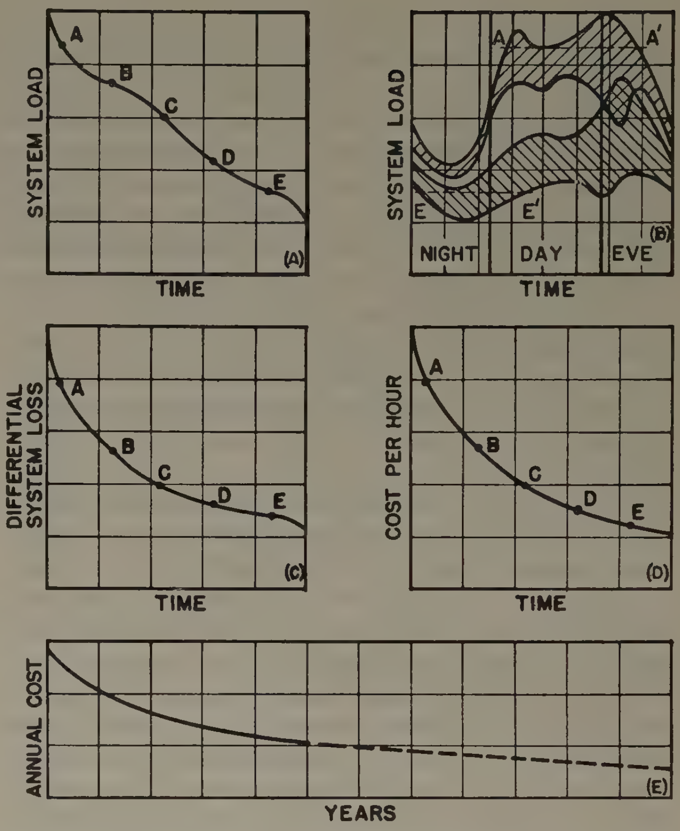


Figure 1. Choice between two power plant sites. (A) Annual load duration curve for system. (B) Envelope of daily load curves for system. (C) Differential annual loss duration curve for system. (D) Differential annual cost duration curve. (E) Annual cost for life of plant

By determining these costs for each year and applying a factor to take account of the present worth of future costs, the curve of Figure 1(*E*) is plotted. The present worth concept assigns less value to a dollar spent ten years from now than to one spent today. Therefore, since the value of the differential in losses decreases with time, the important period in the comparison is the first few years when the assumptions can be more accurate. The total difference in energy cost of system losses for the two locations is obtained by integrating the area under the curve of Figure 1(*E*).

Although a particular problem is used here for illustration, the basic principles are applicable to a wide range of problems involving the evaluation of energy differences. The point to be stressed is that the cost of a unit of energy is not a constant for a given system but depends on the type of problem involved.

Digest of paper **51-341**, "Evaluation of Energy Differences in the Economic Comparison of Alternative Facilities," recommended by the AIEE Committee on System Engineering and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

A. P. Fugill is with The Detroit Edison Company, Detroit, Mich.

The Hot Spot Rise Simulator

C. F. BOOK
MEMBER AIEE

V. V. MASON
ASSOCIATE MEMBER AIEE

THE NEED FOR accurate indicaton of hot spot temperatures under both steady-state and transient conditions is well known. This applies to rotating machines and cables as well as to transformers. The deficiences of the available hot spot indicators led to the development of the Hot Spot Rise Simulator. The goal was the production of a reliable instrument which could be tested and adjusted in the field by the relay engineer in the same way that he tests and adjusts an ordinary protective relay. Work was begun in 1946, and the first installations were made early in 1947 at two stations in the Niagara region of The Hydro-Electric Power Commission of Ontario. All major power transformers purchased by this authority since early 1950 are being equipped with these devices.

The Hot Spot Rise Simulator avoids the difficulties encountered with other hot spot indicators by restricting the equipment mounted within the transformer to a rugged thermojunction, Figure 1, and by limiting the remaining equipment to a thermocouple potentiometer and the Rise Simulator device itself, Figure 2. This device is constructed of sheet mica and rustproof metals and has no moving parts. Its output simulates the temperature rise of the hot spot over the top oil in the form of an electromotive force. Its input is obtained from a current transformer, usually situated in a bushing of the transformer whose hot spot temperature is being indicated. Its output potential is a function of the temperature difference between two thermocouple assemblies due to the input current applied to them.

The output is made adjustable to the required value for the particular installation by means of taps on the output for coarse adjustment and a thermal potential divider for fine adjustment. The time constant is adjustable to the desired value to match that of the transformer.

The Rise Simulator meets the usual requirements of a hot spot indicator in that it can be adjusted to indicate correctly at rated load, and in that its output is proportional to the 0.85 power of the square of the input current so that it behaves similarly to a transformer hot spot. Nevertheless, it was thought wise to determine as accurately as possible the effect of the increased oil viscosity at low top-oil temperatures. This investigation showed that the increase in actual hot spot rise at low oil temperatures is offset automatically by the curvature of the electromotive force–temperature characteristic of the copper-constantan thermocouples used for the top-oil temperature. As a result, it is possible to set the Rise Simulator so that at hot spot temperatures of interest it never reads significantly lower than the calculated hot spot temperature over any practically realizable range of top-oil temperature and load, and it never reads high by more than a few degrees. Such an error is less than the uncertainty in the value of the hot spot rise above the top-oil obtained from the heat-run data on the transformer.

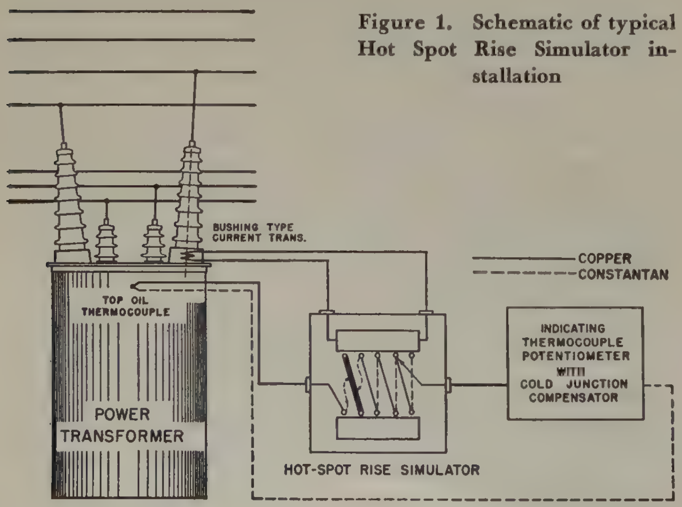

BUSHING TYPE CURRENT TRANS.
COPPER
CONSTANTAN
TOP OIL THERMOCOUPLE
INDICATING THERMOCOUPLE POTENTIOMETER WITH COLD JUNCTION COMPENSATOR
POWER TRANSFORMER
HOT-SPOT RISE SIMULATOR

Figure 1. Schematic of typical Hot Spot Rise Simulator installation

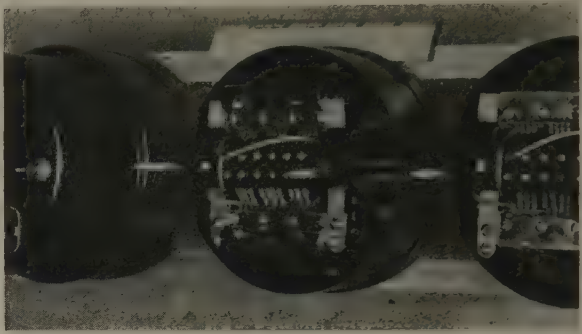


Figure 2. The Hot Spot Rise Simulator: cover on; cover off, 10-minute time constant; cover off, 2.6-minute time constant

The Hot Spot Rise Simulator can be used as a hot spot relay with delayed tripping characteristics by adjusting it for a time constant greater than that of the rise of the transformer winding over the top-oil. This allows a controlled amount of overheating before tripping is initiated, with positive protection under serious overload conditions. It also may be used along with a thermocouple on the lead sheath or stator core as an indicator or relay in connection with hot spot temperatures in cables and generators. In the latter case particularly, it may be used to correct for the large discrepancy which can exist between the indications of a thermocouple placed between coil sides and the true conductor temperature.

Digest of paper 51-247, "The Hot Spot Rise Simulator," recommended by the AIEE Committee on Instruments and Measurements and approved by the AIEE Technical Program Committee for presentation at the AIEE Summer General Meeting, Toronto, Ontario, Canada, June 25–29, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

C. F. Book is with The Hydro-Electric Power Commission of Ontario, Niagara Falls, Ontario, Canada and **V. V. Mason** is with The Hydro-Electric Power Commission of Ontario, Toronto, Ontario, Canada.

Selection of Field Circuit Resistance for Synchronous Motors

W. A. THOMAS
MEMBER AIEE

O. D. WHITWELL
ASSOCIATE MEMBER AIEE

Designers and users of synchronous motors will find in this article a proposed system for changing the starting performance of these motors through selection of the proper field circuit discharge resistance. A review of present starting control methods is given also.

THE STARTING performance of salient-pole synchronous motors has been given much study by designers and users of these machines; however, only a few comprehensive articles appear in the literature on the subject. Fechheimer[1] published the first study of the starting characteristics of synchronous motors in 1912. Since that time others have extended these studies in keeping with the developments in synchronous machines. As the theory developed, it became more and more involved with the numerous factors which are now known to enter into the prediction of synchronous motor performance. The result has been a maze through which only those well versed in design have found their way.

After fabrication of the motor is complete, the application engineer has available only a limited number of external factors with which to control the performance of the machine. Among these are the terminal voltage to be applied on starting (including both the method of reducing the starting voltage and the value necessary to compensate for such factors as line voltage drop and system capacity), the exciter voltage, the field rheostat, and the external field circuit resistance. Of these items little information is available concerning the selection of the external field circuit resistance. As will be shown, the external resistance in the field circuit may be of considerable importance in the starting performance of synchronous motors. Since this resistance is one of the variables which the user (or the control manufacturer) may determine, a system for easily selecting this resistance should be devised. This article develops one possible method.

SYNCHRONOUS MOTOR STARTING THEORY

THE STARTING PERIOD of a synchronous motor is defined as the time from the application of voltage to the primary winding (at zero speed) until the rotor speed is 95 per cent of synchronous speed. Practically all present-day synchronous motors operate as squirrel-cage induction motors during the starting period. As with the induction motor, the torque developed by the rotor is proportional to the in-phase component of the rotor current and the rotor resistance. The starting performance may be varied by the designer by changing the squirrel-cage resistance and reactance. Low inrush induced volt-amperes and high starting torque are obtained with a high-resistance squirrel-cage winding having a low reactance. This is shown in Figure 1.

The d-c field winding on the rotor of the synchronous motor has characteristics opposed to this type of winding; consequently, the use of the field circuit as a starting winding is undesirable. However, to protect the field winding from the high induced voltages realized at standstill when line voltage is applied, it is customary to close the field circuit through a field discharge resistance. If this resistance is of low value the power factor of the rotor will be low, the field being highly inductive, and the in-phase component of the current will be reduced. The use of a high value of resistance in the field circuit will increase the power factor and the starting torque will be increased proportionately.

In either the induction motor or the synchronous motor a higher torque is realized at speeds near synchronism with a low-resistance squirrel-cage winding. See Figure 1. This phenomenon may be explained as being the result of the reduction in rotor reactance at the lower frequency voltages induced in the rotor near synchronism. As a result of this reduced reactance, the power factor of the rotor is improved, the in-phase component of current is increased, and the torque (rotor I^2R) is increased. Since

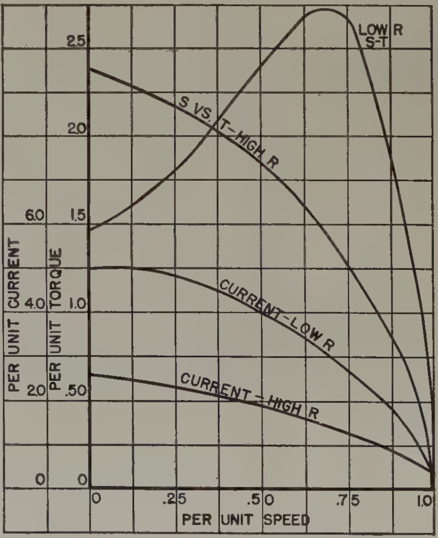


Figure 1. Typical induction motor curves. Single squirrel-cage rotor winding

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Full text of paper 51-377, "The Selection of Field Circuit Resistance for Synchronous Motors," recommended by the AIEE Committee on Industrial Control and approved by the AIEE Technical Program Committee for presentation at the AIEE Fall General Meeting, Cleveland, Ohio, October 22–26, 1951. Scheduled for publication in AIEE *Transactions*, volume 70, 1951.

W. A. Thomas is with the Case Institute of Technology, Cleveland, Ohio, and **O. D. Whitwell** is with the Clark Controller Company, Cleveland, Ohio.

this condition is obtained with conditions adverse to the conditions for high starting torque, a double squirrel-cage winding may be employed. Windings of this type exhibit the speed-torque characteristics shown in Figure 2. These characteristics result because the rotor has a high effective resistance when starting and a low effective resistance near synchronous speed.

Practice has shown that a synchronous motor having a single squirrel-cage winding and the proper resistance across the d-c field may have the same characteristics as the double squirrel-cage winding. In Figure 3 it is seen that increasing R_{fe} (field circuit resistance) flattens the cusp of the speed-torque curve and increases both the starting and pull-in torques.

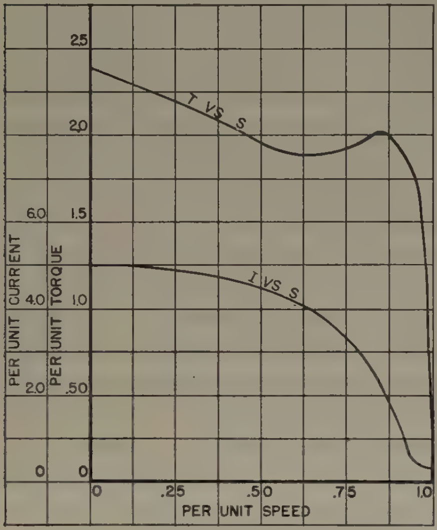


Figure 2. Typical induction motor curves. Double squirrel-cage rotor winding

The double squirrel-cage starting winding, giving low starting kilovolt-ampere inrush and good starting, accelerating, and pull-in torques, is an ideal starting winding for synchronous motors. The use of the proper values of R_{fe} with a standard single-cage synchronous motor will provide these characteristics at less cost in many applications. This results because the use of double squirrel-cage windings increases the first cost of the motor and decreases its efficiency somewhat under operating conditions. The decrease in efficiency is due to the extra weight and higher leakage caused by the added pole-face thickness necessary for imbedding the double squirrel-cage winding.

LIMITING INDUCED FIELD VOLTAGES

At the instant of applying the starting voltage to the stator of a synchronous motor, a voltage induced by transformer action appears across the open field winding. The value of this voltage is determined by the ratio of total d-c field winding turns to the effective turns of the stator. A large number of turns are often necessary in the field winding to obtain sufficient excitation, resulting in a high turns ratio and a high induced voltage in the field winding.

This high voltage is detrimental to the field insulation, and precautions are essential in preventing voltages in excess of the rating of the insulation. Although a sectionalized field winding sometimes is employed, the most used provision is a field discharge resistor in series with the field circuit. An approximate value of this resistor may be determined from the ratio of the maximum permissible induced voltage to the current that is induced in the short-circuited field on starting with rated voltage applied. The resistance found is a conservative value which will limit the voltage to a value less than that taken as permissible. This is partially corrected by the general practice of subtracting the ohmic value of the internal field resistance from this conservative value.

A somewhat more accurate value may be obtained through knowledge of the maximum allowable field current (I_f) and the field impedance ($Z_f = R_f + jX_f$) at rated line frequency. The total required field circuit impedance in ohms then will be

$$Z_T = \frac{\text{maximum allowable induced voltage}}{\text{maximum allowable } I_f}$$

Z_T is composed of the field impedance plus the external field resistance (R_{fe}). Therefore

$$Z_T = R_T + jX_f$$

and

$$R_{fe} = R_T - R_f$$

If complete design is available on a particular class of motors, an equivalent circuit[3–6] such as is shown in Figure 4 may be calculated on a per-unit basis and the necessary discharge resistance predetermined.

A discharge resistor generally is connected across the field to limit the induced voltage when the d-c excitation is removed. The same resistor used to limit the induced voltages on starting may be employed in this application provided it is of the proper value. This is readily checked with the familiar equations for d-c transient conditions in circuits containing resistance and inductance in series.

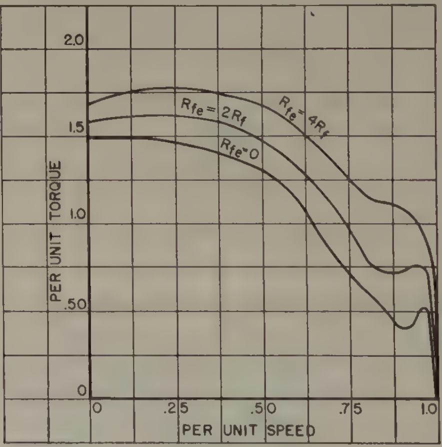


Figure 3. Typical synchronous motor starting performance curves

$$e_i = \frac{R_{fe}}{R_f} V \epsilon^{-(R_{fe}+R_f)t/L}$$

where e_i = instantaneous induced voltage; V = rated d-c excitation voltage; R_f and L_f = field resistance and inductance, respectively; R_{fe} = external resistance in series

Table I. NEMA Classification of Synchronous Motors and Normal Torque Requirements

A. General Purpose Motors

Power Factor and Horsepower	Speed, Rpm	Per Cent of Rated Torque: Locked Rotor	Pull-in	Pull-out
1.0 pf to and including 200 hp	1,800	110	110	150
	1,200–514	110	110	175
0.8 pf to and including 150 hp	1,800	110	110	200
	1,200–514	110	110	250

B. Large High-Speed Motors: 514 Rpm and Up

Power Factor and Horsepower	Speed, Rpm	Per Cent of Rated Torque: Locked Rotor	Pull-in	Pull-out
1.0 pf, 250–500 hp	1,800–514	110	110	150
0.8 pf, 200–500 hp	1,800–514	125	125	200
1.0 pf, 600 hp and up	1,800–514	85	85	150
0.8 pf, 600 hp and up	1,800–514	100	100	200

C. Low-Speed Synchronous Motors: 450 Rpm and Lower

Power Factor	Per Cent of Rated Torque: Locked Rotor	Pull-in	Pull-out
1.0	40	30	150
0.8	40	30	150

with field circuit; t = time after opening field circuit; and $\epsilon = 2.718$.

The maximum induced voltage occurs at the instant of interrupting the field circuit (at $t=0$), so the maximum induced voltage simply becomes

$$E_m = \frac{R_{fe}}{R_f} V$$

FIELD CIRCUIT RESISTANCE AND STARTING

THE EQUIVALENT circuits referred to previously present convenient means for calculating the performance of synchronous motors from design or test data. No equivalent circuit or scheme of calculating motor performance has been proposed which offers an over-all accuracy greater than about 5 per cent. However, accuracy within 5 or 10 per cent is adequate in modern engineering procedure where any precision attained in the calculations is modified by the demands of manufacturing, economics, standardization, and so forth. This philosophy prevailing, a proposal for the control of synchronous motor starting performance through selection of the field discharge resistance is presented.

The standard torque specifications for synchronous motors of the National Electric Manufacturers Association (NEMA) are shown in Table I. As indicated in these tables, all synchronous motors having standard horsepower, speed, and power factor ratings are in three general categories: 1. general purpose synchronous motors, 2. large high-speed synchronous motors, and 3. low-speed synchronous motors. These classifications are subdivided according to speed, horsepower, and power factor ratings.

If ample quantities of design or test data were available to supply the per-unit values of each impedance for a synchronous motor equivalent circuit, an average "per-unit" motor could be determined based on an average of the individual per-unit values from each of a multitude of motors. Comprehensive data encompassing motors with ratings throughout the entire range of NEMA classifications and subdivisions should be compiled and analyzed. If the per-unit values exhibit excessive deviation, further subdivision of the general classifications will be required. The data also may indicate an increase of input reactance (and the resulting decrease in starting inrush current and torque) with increasing horsepower ratings and decreasing speed ratings. This fact alone may necessitate the further subdivisions.

A comprehensive study of the data will result in approximately eight or ten per-unit motors. Supplying the per-unit impedances of each of these average motors in the equivalent circuit provides a means of calculating the motor performance. The torque-speed characteristic is determined by assuming values of slip for each point on the curve and calculating the resulting torque in terms of the rotor power input.

To determine the effect of the external field circuit resistance on the starting performance, it becomes necessary to assume values of external field resistance and then to calculate the resulting torque-speed relation. The starting torque and the pull-in torque are the most important points in the starting period. Therefore, a tabulation of the results calculated at zero speed (slip=1.0) and at 95-per cent synchronous speed (standard pull-in slip=0.05) may suffice. The values of external field resistance to assume in performing these calculations should range from a short circuit to a maximum value determined by the dielectric strength of the insulation.

The calculation of complete torque-speed curves for each value of field circuit resistance may be advantageous. The family of curves so revived may illustrate the possibility of using some form of field acceleration in the application of synchronous motors: for example, an application requiring low inrush kilovolt-amperes and very high starting torque and also a very high pull-in torque. These conditions are satisfied by utilizing a very high resistance and removing it in steps as the motor comes up to speed.

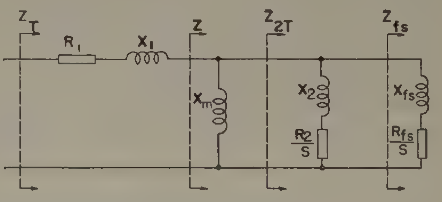


Figure 4. Equivalent circuit of a salient-pole synchronous motor having a single squirrel-cage starting winding

EXAMPLE OF THE EFFECT OF FIELD RESISTANCE

IN THIS SECTION the calculation of the effect of changing the field discharge resistance is applied to a per-unit motor in the NEMA Classification of General Purpose Synchronous Motor,[7] unity power factor.

The equivalent circuit of Figure 4 was utilized because of its relative simplicity, and its proved ability and accuracy commensurate with practical synchronous motor design. In lieu of comprehensive machine design data from which to determine average per-unit data, design data from a

Table II. Effect of External Field Resistance (R_{fe}) on Synchronous Motor Starting Performance

R_{fe}	Starting Torque	Pull-in Torque	Starting Kva Inrush	Starting Power Factor	Torque Kva Inrush
0	0.87	0.88	6.0	0.254	0.145
$1R_f$	0.877	1.166	6.0	0.255	0.1462
$2R_f$	0.888	1.36	6.0	0.256	0.147
$3R_f$	0.89	1.46	6.0	0.257	0.1473
$4R_f$	0.896	1.515	6.0	0.259	0.1493
$5R_f$	0.916	1.71	6.01	0.262	0.153
$6R_f$	0.911	1.52	6.015	0.262	0.151
$7R_f$	0.915	1.478	6.01	0.262	0.1528
$8R_g$	0.914	1.465	6.0	0.262	0.1524
$9R_f$	0.916	1.455	6.0	0.262	0.153
$10R_f$	0.928	1.42	6.0	0.264	0.1548
$12R_f$	0.93	1.368	6.0	0.261	0.155
$25R_f$	0.009	1.19	6.0	0.279	0.168
$100R_f$	1.099	1.14	5.85	0.318	0.187
Open field	1.11	0.818	5.47	0.31	0.19

Table III. Effect of External Field Resistance (R_{fe}) on the Rotor Current (I_2) and the Total Effective Rotor Resistance (R_{2T})

R_{fe}	Starting; R_{2T}	Slip=1.0 I_2	Pull-in; R_{2T}	Slip=0.05 I_2
0	0.0286	5.52	0.1465	2.45
$1R_f$	0.02875	5.525	0.193	2.46
$2R_f$	0.029	5.53	0.236	2.4
$3R_f$	0.0291	5.53	0.274	2.31
$4R_f$	0.02922	5.54	0.3095	2.22
$5R_f$	0.03015	5.53	0.3595	2.18
$6R_f$	0.0296	5.55	0.37	2.026
$7R_f$	0.0298	5.54	0.394	1.94
$8R_f$	0.03	5.52	0.406	1.9
$9R_f$	0.0302	5.51	0.435	1.83
$10R_f$	0.0304	5.53	0.461	1.743
$12R_f$	0.0305	5.52	0.496	1.66
$25R_f$:	0.033	5.53	0.63	1.345
$100R_f$	0.043	5.45	0.82	1.05
Open field	0.0455	4.94	0.91	0.948

single motor were employed for purposes of illustrating the method.

The results of the computations are found in Tables II and III. Analysis of these tabulated data discloses a number of effects produced by changes in the field circuit resistance.

1. The starting torque increases with increasing d-c field circuit resistance (R_{fe}) because an increasing resistive element in the secondary circuit (Z_{2T}) causes the total equivalent secondary resistance (R_{2T}) to increase. (See Table III.) The equivalent secondary reactance (X_{2T}) at the starting frequency remains at essentially a constant value of a larger order of magnitude than the effective resistance. Consequently, the secondary current is practically independent of the magnitude of the resistance. Since the torque developed is proportional to the rotor power ($I_2^2R_{2T}$), the torque will increase with increasing R_{fe}.
2. The starting power factor increases with increasing R_{fe}, a consequence of the increasing resistance reflected into the primary as the secondary resistance is increased.
3. The starting inrush remains essentially constant until large enough values of field resistance exist to increase the input impedance appreciably. Since the effective turns ratio of the sample machine is approximately 25-to-1, this effect is not appreciable in the normal range of R_{fe}.
4. The starting torque per kilovolt-ampere inrush factor is indicative of the starting efficiency, and is observed to increase steadily in proportion to the increasing starting torque. This prevails because of the practically constant inrush.
5. Table II indicates that the pull-in torque is not strictly a function of the secondary resistance. At slip frequency, the reactance is nearly constant, and the equivalent circuit becomes a fixed reactance in series with a variable resistance. The locus of the current in such a circuit is a circle having a diameter proportional to the value of current when the current is lagging 90 degrees behind the applied voltage. As the resistance is increased the current decreases in magnitude from a maximum at 90 degrees lagging to zero at infinite resistance. The power consumed (and consequently the torque of the motor) in such a circuit is then a maximum at the point where the magnitude of the resistance is equal to that of the reactance.

Table II indicates this point to be at an external field resistance of approximately five times the field resistance.

6. Also of interest is the magnitude of the excursions made by the starting and pull-in torque from the rated values. The starting torque may be reduced 3 per cent and increased 21 per cent (from the 0.90 design value) by variations from short circuit to open field. Over the same range of external resistances, the pull-in torque varies from 60 per cent below to 20 per cent above the design value of 1.5.

CONCLUSION

The change in starting torque with change in field circuit resistance of normally used values is small, the starting torque depending primarily upon the resistance and reactance of the squirrel-cage winding. However, the field resistance does have an appreciable effect on the pull-in torque. This indicates that the selection of a synchronous motor should be determined primarily from the starting torque requirements of the load. Then the pull-in torque requirements of the load may be met through control of the value of the field resistor.

The use of the per-unit motor suggested previously and the data resulting from the calculations would greatly facilitate the selection of the correct field circuit resistance for the synchronous motor. It is believed that this proposal is the first comprehensive scheme of application information ever presented for any electric machine. Consequently, the intentions are to indicate the need for such application information and to instigate the prerequisite thought for development of a system of application data which eventually may be applied to all types of electric apparatus.

REFERENCES

1. Self-Starting Synchronous Motors, **C. J. Fechheimer.** AIEE *Transactions*, volume 31, part I, 1912, pages 529–604.

2. Behavior of Synchronous Motors During Starting, **F. D. Newbury.** AIEE *Transactions*, volume 32, part II, 1913, pages 1509–25.

3. Starting Performance of Synchronous Motors, **H. V. Putnam.** AIEE *Transactions* volume 46, part II, 1927, pages 39–57.

4. Starting Performance of Salient Pole Synchronous Motors, **T. H. Linville.** AIEE *Transactions*, volume 49, 1930, pages 531–47.

5. Starting Performance of Salient Pole Synchronous Motors, **M. K. Liwschitz.** AIEE *Transactions*, volume 59, 1940, pages 913–19.

6. Design of Electrical Apparatus (book), **J. H. Kuhlmann, N. F. Tsang.** John Wiley and Sons, New York, N. Y., third edition, 1950.

7. Standards for Motors and Generators, National Electrical Manufacturers Association Report. *NEMA publication number MG1-1949* (as revised June 1, 1951), (New York, N.Y.), part 8, page 29, paragraph MG1-8.14.

INSTITUTE ACTIVITIES

Charles E. Wilson to Be Principal Speaker at Winter General Meeting

The AIEE Winter General Meeting to be held at the Hotel Statler in New York, N. Y., January 21–25, will feature a well-diversified program of technical and social activities. The technical program is one of the largest in the history of the Institute with all available meeting rooms in constant use. A group of inspection trips has also been arranged closely allied with the technical sessions and conferences.

Charles E. Wilson, Director, Office of Defense Mobilization, will deliver the keynote address at the general session to be held at 2:00 p.m., Monday, January 21. Mr. Wilson, a dynamic speaker and organizer, will talk on a subject most timely in this fast-moving period of national and world events. President F. O. McMillan will open the general session with an address to the members assembled.

At this session the Edison Medal will be presented to C. F. Wagner, Consulting Engineer, Westinghouse Electric Corporation; Mr. Wagner is a Fellow of the Institute. Also the Institute Prize Paper awards will be made.

The Alfred Noble Prize for an outstanding technical paper by an author under 31 years of age has been awarded to Eldo C. Koenig, Electrical Department, Allis-Chalmers Manufacturing Company; Mr. Koenig is an Associate Member of the Institute. The Alfred Noble Prize is a joint interest of the various Founder societies and the Western Society of Engineers. Carlton Proctor, President of the American Society of Civil Engineers, will give the address in connection with the presentation of the prize.

On the social side of the meeting, there will be a dinner-dance, a smoker, theater tickets for out-of-town members, and special entertainment for the ladies.

TECHNICAL PROGRAM

The technical program and most of the committee meetings will be held in the Hotel Statler.

One of the most timely sessions is entitled "Color Tubes for Television." The program will include papers on both the Radio Corporation of America (RCA) and Lawrence color tubes for television receivers. Not only will technical papers describing the two tubes be presented, but there will be a demonstration in connection with the delivery of the RCA color tube paper. The Lawrence tube will be exhibited also.

Another session of such general interest that engineers in many fields may wish to attend is on "The Mechanism of Communication." The three speakers are experts in fields greatly affecting all engineers but in which most engineers are not unduly proficient. While the particular fields of the first two speakers are public speaking and writing respectively, the peculiar problems of engineering communications have been the subject of much study on their part and their conclusions will be helpful to all engineers. Both are professors at New York University. The third speaker is a scientist and engineer at the Bell Telephone Laboratories who has been closely associated with Mr. C. E. Shannon and others who have contributed to the new Communication Theory which has aroused so much interest. This talk will make clear to the average engineer what this mysterious subject is about and approximately what the gains from it may be.

In addition to the meeting just mentioned, sessions pertaining to communications will cover recent developments in Communication Switching Systems, Facsimile, Wire and Radio Telegraph Systems, and Mobile Radio Systems.

The Science and Electronics Group has arranged for the technical sessions on the following subjects: Basic Sciences, Instruments and Measurements, Computing Devices, Magnetic Amplifiers, Electrical Properties of Gases, Semiconductors and Transistors, Magnetics, Electronic Instruments, and Metallic Rectifiers.

Sessions on General Applications will include Light and Heavy Traction, Space Heating, and Heat Pumps.

The Industry Groups' sessions will cover Industrial Control, Electronics in Industry, Electrical Applications in Pipe-Line Transportation, Electric Heating, Industrial Power Systems, and Feedback Control Systems.

The Power Group has scheduled sessions covering Carrier Current, Protective Devices, Substations, Switchgear, Power Generation, Transmission and Distribution, Rotating Machinery, Relays, Transformers, Insulated Conductors, and System Engineering.

In addition, sessions are being sponsored by the following committees in our Professional Group: Management, Safety, and Education.

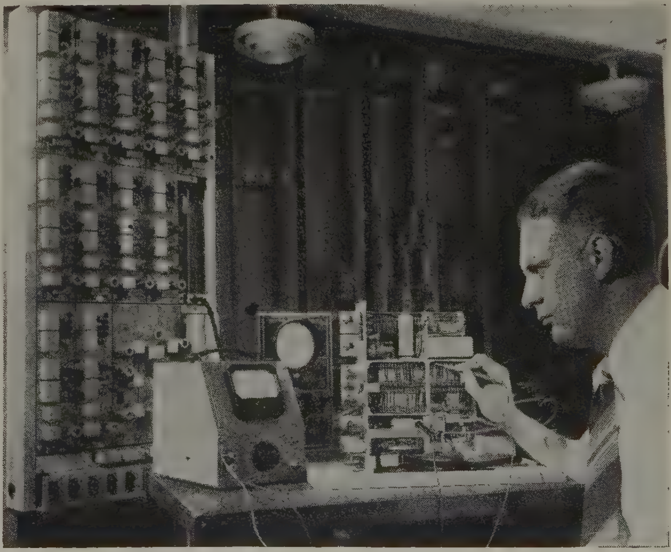
In connection with the presentation of his paper "Mapping Techniques Applied to Fluid Mapper Patterns," Professor A. D. Moore of the University of Michigan will give a lecture-demonstration of a fluid mapper. In a fluid mapper the fluid flows in streamline fashion. The flow pattern is made visual by dye lines formed by potassium permanganate crystals. These flow patterns simulate electrostatic, magnetic, heat flow, and other fields and can lead to their solution. A dental stone slab for a mapper will be cast, finished, and operated in a fluid mapper. A tilted mirror enables the audience to follow every step. Color slides of many fluid mapper patterns will be shown.

INSPECTION TRIPS

A program of inspection trips of technical and general interest has been arranged for those attending the Winter General Meeting. Since the number who may be accommodated in most of these trips is limited, members are urged to make arrangements for trips immediately upon registering at meeting headquarters. Advance registration by mail for inspection trips cannot be accepted. It will be necessary to comply with such security regulations as are in force at the time of each of the inspection trips.

Radio City Music Hall, New York, N. Y. (Tuesday morning, January 22). This is a repeat performance by popular request. Famous for entertainment quality and notable for achieving the spectacular, Radio City Music Hall is foremost in applying engineering development to the entertainment field. Revolving and sectionalized stages, elevating orchestra pits, motorized curtains, fantastic lighting, and a multitude of mechanical and electrical controls are shown and described on this trip. The magnitude of these operations is indicated by the connected load of 5,500 horsepower in motors and 3,500 kw of lighting.

(*Continued on page 92*)



A channel unit of an N-1 carrier terminal is being checked by an engineer to verify characteristics at the Bell Telephone Laboratories, one of the inspection trips to be taken during the Winter General Meeting

Tentative Technical Program

Winter General Meeting, New York, N. Y., January 21-25

Monday, January 21

10:00 a.m. Carrier Current

52-96. Proposed Definitions Relating to Power-Line Carrier. *Carrier Current Project Committee.* Presentation by title only for discussion

52-97. A Power-Line Carrier System for Maximum Channel Utilization. *J. A. Doremus,* Motorola, Inc.

52-98. Carrier-Frequency Characteristics of Power Transformers. *T. R. Specht, R. C. Cheek,* Westinghouse Electric Corporation

52-99. Input Filter Design for Frequency-Modulated Power-Line Carrier Receivers. *R. L. Fillmore,* University of Minnesota

10:00 a.m. Conference on Protective Devices

51-285—ACO.* Lightning-Arrester Application Guide—Preliminary Working Group Report. *Project Committee on Application Guide of Methods for Lightning Protection of Substations.* (NOTE: Advance pamphlet copies of this paper are not available for sale as the previous supply has been exhausted.)

10:00 a.m. Substations

52-21. Basic Structural Design for Transmission Substations Including Light Metals. *Substation Committee Project Number 8*

CP. Outdoor Substation Standardization Saves Critical Engineering Time.** *A. H. Powell, C. B. Hinton*

CP. Substation Grounding Practices.** *Committee on Substations Working Group*

52-22. Automatic Phase Angle and Voltage Control of Unattended Marcus Hook Substation. *W. A. Derr,* Westinghouse Electric Corporation; *F. H. Travers,* Philadelphia Electric Company; *R. M. Jolly,* City Public Service Board of San Antonio

10:00 a.m. Land Transportation

52-23. A New Electric Locomotive for the Pennsylvania Railroad. *F. D. Gowans, B. A. Widell, A. Bredenberg,* General Electric Company

52-24. The Pennsylvania Railroad Ignitron-Rectifier Locomotive. *C. C. Whittaker, W. M. Hutchison,* Westinghouse Electric Corporation

CP. Progress of Electrification in Europe with Special Emphasis on the ANNECY Conference.** *H. F. Brown,* New York, New Haven and Hartford Railroad

CP. Impressions of European Electrification Including the New Single-Phase 50-Cycle System in France and Possible Bearing on U. S. Electrification.** *J. C. Aydelott,* General Electric Company

52-18. Railway Power Contracts. *T. M. C. Martin,* Bonneville Power Administration

52-25. Railway Electrification, Diesel-Electric Locomotives and Some Future Aspects of Electric Traction. *G. Huldschimer,* College of City of New York

10:00 a.m. Industrial Control

CP. Fundamental Considerations in the Use of Feedback Control.** *O. W. Livingston*

CP. Regulators from the Electronic Point of View.** *E. H. Vedder,* Westinghouse Electric Corporation

CP. Rotating Regulator Applications in the Steel Industry.** *W. R. Harris,* Westinghouse Electric Corporation

CP. Synthesizing the Armature Circuit of a D. C. Shunt Motor Supplied by Half Wave Rectifier.** *W. S. Kupfer, Jr., E. E. Moyer*

10:00 a.m. Electric Space Heating and Heat Pumps

CP. Experiences with Compression-Type Electric Water Heaters.** *M. S. Oldacre,* Utilities Research Commission

CP. Residential Heat Pump Experiments in Philadelphia—Installation and Operating Experience.** *J. H. Harlow, G. E. Klapper,* Philadelphia Electric Company

CP. Residential Heat Pump Experiments in Philadelphia—Earth as a Heat Source.** *A. H. Kidder, J. H. Neher,* Philadelphia Electric Company

CP. Residential Heat Pump Experiments in Philadelphia—Suggested Possibilities for Practical Applications.** *Constantine Bary,* Philadelphia Electric Company

CP. A New Packaged Heat Pump.** *H. G. Fifield, C. I. Bacheller,* General Electric Company

52-69. Application of Motors to Household Refrigeration Compressors. *L. C. Packer,* Westinghouse Electric Corporation

9:30 a.m. Switchgear

52-27. Short-Circuit Ratings of Power Circuit Breakers. *R. C. Van Sickle,* Westinghouse Electric Corporation

52-11. Consideration in Testing, Rating, and Application of Power Circuit Breakers. *Byron Evans, C. L. Killgore,* Bureau of Reclamation

52-17. Correlation of Interrupting Rating and Application of Power Circuit Breakers. *J. A. Elzi,* Commonwealth Services, Inc.

52-28. The Effect of Current Asymmetry on Circuit Interruption. *W. F. Skeats,* General Electric Company

52-29. Considerations in the Rating and Testing of Power Circuit Breakers. *H. P. St. Clair, Otto Naef,* American Gas and Electric Service Corporation

2:00 p.m. General Session

Address: *President F. O. McMillan*

Presentation of the **Edison Medal** to *C. F. Wagner*

Presentation of the **Alfred Noble Prize** to *Eldo C. Koenig*

Presentation of Institute Prizes

Address: *Charles E. Wilson,* Director, Office of Defense Mobilization

The American Society of Civil Engineers Centennial of Engineering 1952—Announcement

Tuesday, January 22

9:30 a.m. Switchgear

52-20. New High-Capacity Switchgear Testing Laboratory. *V. L. Cox,* General Electric Company

52-10. High-Speed Multiple Reclosing Oil Circuit Breaker for 161 Kv 10,000,000 Kva. *B. P. Baker, G. B. Cushing,* Westinghouse Electric Corporation

52-30. High-Voltage Circuit Breakers in the Bonneville Power System. *O. A. Demuth, A. Dovjikov,* Bonneville Power Administration

52-31. Ultra-High Capacity Field Tests on 230-Kv Air-Blast Circuit Breaker at Grand Coulee Power Plant. *A. C. Conger, C. L. Killgore,* Bureau of Reclamation; *Dr. William Wanger,* Brown, Boveri and Company, Baden, Switzerland

52-16. Out-of-Phase Switching Voltages and Their Effect on High-Voltage Circuit Breaker Performance. *W. M. Leeds, D. J. Povejsil,* Westinghouse Electric Corporation

9:30 a.m. Power Generation Excitation Systems

52-33. Selection of Characteristics for Turbine-Generator Motor-Driven Exciters. *H. G. Frus,* Duquesne Light Company; *F. N. McClure, W. H. Ferguson,* Westinghouse Electric Corporation

52-34. Experience with Automatic Voltage Regulation on a 115-Megawatt Turbogenerator. *H. A. Cornelius, W. F. Cawson,* Public Service Company of Northern Illinois; *H. W. Cory,* Allis-Chalmers Manufacturing Company

CP. Static Stability Considerations for Proposed Turbine-Generator Ratings.** *R. F. Lawrence, A. A. Johnson,* Westinghouse Electric Corporation

CP. Power Generation Equipment for the Future.** *W. A. Hirt*

9:30 a.m. Conference on Dielectrics

CP. Interpretation of the Dielectric Behavior of Solid Long-Chain Derivatives.** *J. D. Hoffman,* General Electric Company

CP. Lanosterol—A New High Dielectric Constant Dielectric.** *W. McMahon, G. T. Kohman,* Bell Telephone Laboratories, Inc.

CP. Electrical and Physical Properties of IN-420—A New Chlorinated Liquid Dielectric.** *A. J. Warner,* Federal Telecommunication Laboratories

CP. Impulse Dielectric Strength Characteristics of Liquid Impregnated Pressboard.** *T. W. Dakin, C. N. Works,* Westinghouse Electric Corporation

CP. The Effect of Increasing Frequencies on Dielectric Strength of Electrical Insulators.** *J. J. Chapman,* The Johns Hopkins University

9:30 a.m. Electronics in Industry

CP. Electronics in Textiles.** *F. D. Snyder, L. T. Jester*

CP. Electronic Control of Machine Tools.** *J. M. Delfs*

CP. The Use of Electronics for Material Handling Systems.** *J. C. Webb*

52-101. Theory of Electric Spark Machining. *E. M. Williams,* Carnegie Institute of Technology

52-1. Tests of Electrostatic Controls for Hazardous Industrial Applications. *Robin Beach,* Engineers Associated. Presentation by title only for discussion

9:30 a.m. Electronic Instruments

CP. Over-Temperature Monitor for Multiple Thermocouple Systems.** *F. H. Bayhi, Jr., M. L. Greenough, M. Martens,* National Bureau of Standards

CP. An Electronic Peak Reading Kilovoltmeter.** *R. E. Brueckmann,* National Bureau of Standards

CP. An Elliptical Polarization Synthesizer.** *G. H. Friedman*

CP. A System for Measuring Change of Phase Path of Pulsed Radio Signals Vertically Incident on the Lower Ionosphere.** *R. E. Jones*

CP. Measurement of High-Frequency Speed Variation in Rotating Equipment.** *E. G. Manning*

9:30 a.m. Metallic Rectifiers

CP. Comparative Characteristics of Metallic Rectifiers.** *E. A. Harty,* General Electric Company

52-100—ACO.* Automatic Regulation of Metallic Rectifiers by Electronic Control. *J. A. Potter,* Reeves Instrument Corporation

CP. Recent Applications of Selenium Rectifiers.** *O. S. Aikman,* Fansteel Metallurgical Corporation

CP. High-Voltage Selenium Rectifiers.** *I. R. Smith,* Westinghouse Electric Corporation

CP. Capacitor Loading of Metallic Rectifiers.** *C. E. Hamann,* General Electric Company

52-102. Automatic Regulation of Metallic Rectifiers by Magnetic Control. *D. H. Smith,* Bell Telephone Laboratories, Inc.

9:30 a.m. Land Transportation

52-35. A New Wheel-Slip Protective Scheme. *R. M. Smith,* General Electric Company

CP. The Theory and Practice of Wheel Control.** *C. L. Eksergian,* The Budd Company

52-36. Co-ordinated Transportation for Large Metropolitan Communities. *E. E. Kearns,* General Electric Company

52-37. New Series-Type Motor for Trolley Coaches. *G. M. Woods, C. R. Steen,* Westinghouse Electric Corporation

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* ACO: Advance copies only available; not intended for publication in *Transactions.*

** CP: Conference paper; no advance copies are available; not intended for publication in *Transactions.*

52-38. A New Control for Trolley Coaches. *N. H. Willby*, Westinghouse Electric Corporation

9:30 a.m. Communication Switching Systems

CP. European Switching Systems.** *H. H. Schnecklo th*

CP. European Switching Apparatus.** *A. C. Keller*

CP. Survey of Telephone Switching in Alaska.** *D. L. Solomon*

CP. Development of REA Requirements for Switching Equipment in the U. S. A.** *R. S. Neikirk*

2:00 p.m. Switchgear

52-39. Switching Capacitive Kilovolt-Amperes With Power Circuit Breakers. *N. E. Dillow, I. B. Johnson, N. R. Schultz, A. E. Were*, General Electric Company

52-40—ACO.* New Design Concepts Applied to a Side Break Outdoor Disconnecting Switch. *H. R. Harrison*, General Electric Company

52-41—ACO.* Refinements in Dual Selective Overcurrent Trip Design. *Carl Thumin*, I-T-E Circuit Breaker Company

52-42—ACO.* A New Design of Metal-Clad Switchgear. *J. G. Torbit*, General Electric Company

52-15—ACO.* A New Line of Magnetic-Type Power Circuit Breakers for Metal-Clad Switchgear. *R. B. Shores, E. T. McCurry*, General Electric Company

2:00 p.m. Power Generation, Hydroelectric Systems

52-43. Performance of a New Magnetic Amplifier Type Voltage Regulator for Large Hydroelectric Generators. *G. K. Kallenbach*, Niagara Mohawk Power Corporation; *F. S. Rothe, H. F. Storm*, General Electric Company; *P. L. Dandeno*, Hydro-Electric Power Commission of Ontario

52-44. Application of Hydrostatic Lubrication to Vertical Water Wheel Generator Thrust Bearings. *J. E. Housley, T. L. Corey*, Aluminum Company of America; *G. E. Peterson*, Westinghouse Electric Corporation

CP. Experience in Operation of Hydroelectric Generator Bearings.** *J. P. Fraser*, British Columbia Electric Company, Ltd.

CP. Experience with Bearings on Hydro-Electric Generating Units.** *J. M. Sharpe, A. L. Hough*, Shawinigan Water and Power Company

2:00 p.m. Conference on Dielectrics

CP. The Electrical, Physical, and Chemical Properties of MYLAR Polyester Film.** *R. C. Krueger, A. B. Ness*, E. I. du Pont de Nemours and Company

CP. Polyethylene Terephthalate—Its Use as a Capacitor Dielectric.** *M. C. Wooley, G. T. Kohman, M. C. McMahon*, Bell Telephone Laboratories, Inc.

CP. Corona Studies on Silicone Rubber.** *S. I. Reynolds*, General Electric Company

CP. The Electrical Properties of Glass-Fiber Paper.** *R. T. Lucas, T. D. Callinan*, Naval Research Laboratory

CP. Manufacture and Processing of Mica Paper for Use in Electrical Insulation.** *R. L. Griffeth, E. R. Younglove*, Mica Insulator Company

2:00 p.m. Instruments and Measurements

52-7. Overload Protection of A-C Instruments. *Wilson Pritchett, Elazar Trau*, University of California

52-46—ACO.* A 10-Cycle to 10-Megacycle Gain and Phase Angle Measuring Set. *F. B. Anderson*, Bell Telephone Laboratories, Inc.

CP. A Barium Titanate Accelerometer.** *L. T. Fleming*, National Bureau of Standards

CP.* Shore-Based Radar for Harbor Surveillance. *E. J. Isbister, W. R. Griswold*, Sperry Gyroscope Company

CP. Quantitative Microwave Spectroscopy.** *D. K. Coles*, Westinghouse Research Laboratories

2:00 p.m. The Mechanism of Communication

CP. Humanizing the Technical Speech.** *O. J. Drake*, New York University

CP. Writing Visually.** *E. L. McAdam, Jr.*, New York University

CP. Exploitation of Message Statistics.** *B. M. Oliver*, Bell Telephone Laboratories, Inc.

2:00 p.m. Conference on Management

CP. Science of Leadership.** *M. J. Evans*, Melvin J. Evans Company

CP. Rotation of Assignment for Executive Development.** *D. S. Sargent*, Consolidated Edison Company of N. Y., Inc.

2:00 p.m. Sections Committee

Wednesday, January 23

9:30 a.m. Distribution

52-13—ACO.* Progress Report on Co-ordination of Construction and Protection of Distribution Circuits Based on Operating Data for Year 1949. *Joint AIEE-Edison Electric Institute Working Group on Co-ordination of Construction and Protection of Distribution Circuits*

CP. Changing Concepts of Weatherproof Wire Use and Protection.** *L. L. Carter*, Anaconda Wire and Cable Company

CP. Advantages and Disadvantages of Electric Distribution about 5,000 Volts.** *W. R. Bullard*, Ebasco Services, Inc.

9:30 a.m. Synchronous Motors

52-32. Supercharged Hydrogen Cooling of Generators. *Sterling Beckwith*, Allis-Chalmers Manufacturing Company

52-47. Improved Cooling of Turbine-Generator Windings. *R. A. Baudry, P. R. Heller, H. K. Reamey, Jr.*, Westinghouse Electric Corporation

52-60. Exciter Polarity Reversals in Voltage-Regulated Aircraft Alternators. *R. P. Judkins*, Westinghouse Electric Corporation; *H. M. McConnell*, Carnegie Institute of Technology

52-83. Induction Motor Damping and Synchronizing Torques. *Charles Concordia*, General Electric Company

51-363. Equivalent Circuits of Reluctance Machines. *Chi-Yung Lin*, Shanghai, China. Presentation by title only for discussion

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—PAMPHLET reproductions of authors' manuscripts of the numbered papers listed in the program may be obtained from AIEE Order Department, 33 West 39th Street, New York 18, N. Y., as noted in the following paragraphs.

—PRICES of papers, irrespective of length, are 30 cents to members (60 cents to nonmembers) whether ordered by mail or purchased at the meeting. Mail orders are advisable, particularly from out-of-town members, as an adequate supply of each paper at the meeting cannot be assured. Only numbered papers are available in pamphlet form.

—COUPON books in nine-dollar denominations are available for those who may wish this convenient form of remittance.

—THE PAPERS regularly approved by the Technical Program Committee ultimately will be published in Proceedings and Transactions; also, each is scheduled to be published in Electrical Engineering in digest or other form.

9:30 a.m. Relays and Carrier Current

52-51. Protective Relaying over Microwave Channels. *H. W. Lensner*, Westinghouse Electric Corporation

52-52. A Phase-Comparison Carrier-Current Relaying System for Broader Application. *N. O. Rice, J. S. Smith*, General Electric Company

52-2. Considerations in Selecting a Carrier Relaying System. *R. C. Cheek, J. L. Blackburn*, Westinghouse Electric Corporation

9:30 a.m. Basic Sciences

CP. Self-Generated Oscillations in the D-C Carbon Arc.** *B. H. List, T. B. Jones*, The Johns Hopkins University

52-84. The Calculation of the Magnetizing Force. *A. A. Halacsy*, Dominica, B. W. I.

52-3. Mapping Techniques Applied to Fluid Mapper Patterns. *A. D. Moore*, University of Michigan

52-116. The Current Status of Dynamic Stability Theory. *F. E. Bothwell*, Cambridge, Mass. Presentation by title only for discussion

52-45. Electromechanical Analogies of a Separately Excited D-C Machine. *R. E. Vowels, W. G. Forte*, The University of Adelaide

52-114. Equations for the Inductance and Short-Circuit Forces of Busses Comprised of Double Channel Conductors. *C. M. Siegel*, University of Virginia; *T. J. Higgins*, University of Wisconsin

52-85. Wave Filter Characteristics by a Direct Method. *R. C. Taylor, Mrs. C. U. Watts*, Western Union Telegraph Company

9:30 a.m. Recent Developments in Electron Emitters

CP. The Nickel Base Indirectly Heated Barium Oxide Cathode.** *A. M. Bounds, P. N. Hambleton*, Superior Tube Company

52-53. Characteristic Shifts in Oxide Cathode Tubes. *W. P. Bartley, J. E. White*, General Electric Company

CP. Lanthanum Boride Cathodes.** *J. M. Lafferty*, General Electric Research Laboratory

CP. Further Developments in the Structure and Methods of Fabricating L-Cathodes.** *R. Levi, O. G. Koppius, J. Lambertson*, Philips Laboratories, Inc.

9:30 a.m. Instruments and Measurements

52-54. A High-Speed Direct-Writing Oscillograph. *A. R. Eckels*, North Carolina State College; *I. S. Blumenthal*, Manhattan Beach, Calif.

52-55. A High-Sensitivity Ratio Instrument for Industrial Resistance Thermometers. *E. W. Clark*, General Electric Company

52-56. Methods and Apparatus Employed in the Testing of Single-Phase A-C Watt-Hour Meters. *F. C. Holtz*, Sangamo Electric Company

CP. Winding Hot-Spot Temperature Equipment for Transformers.** *G. Camilli, A. R. Kimball, H. A. Fohrhaltz*, General Electric Company

9:30 a.m. Safety

CP. Organizing for Effective Accident Prevention.** *H. J. Crisick*, Cleveland Electric Illuminating Company

CP. Some Fundamental Principles for Safe Electrical Design of Appliances.** *G. E. Schall, Jr.*, Underwriters' Laboratories, Inc.

CP. Brief Review of European Electrical Safety Requirements.** *Frank Thornton, Jr.*, Consulting Engineer, Pittsburgh, Pa.

CP. Report on Trends in the Revisions of the National Electrical Code.** *H. H. Watson*, General Electric Company

CP. Progress Report on Electrical Defibrillation.** *W. B. Kouwenhoven*, The Johns Hopkins University

9:30 a.m. New Techniques in Facsimile

CP. General Aspects and Problems of Military Facsimile.** *C. K. Clauer*, Bureau of Ships

CP. Military Design Requirements.** *H. F. Burkhard*, Signal Corps Engineering Laboratories

CP. Automatic Controls on a Facsimile Weather Service Network.** *K. R. McConnell, P. R. Marzan*, Times Facsimile Corporation

CP. A Facsimile System Having Response Linear with Optical Density.** *J. V. L. Hogan, F. A. Hester,* Hogan Laboratories, Inc.

2:00 p.m. Transmission and Distribution

52-104. Sixty-Cycle and Impulse Spark-Over of Large Gap Spacings. *H. J. Hagenguth, A. F. Rohlfs, W. J. Degnan,* General Electric Company

52-105. Impulse Corona—Detection, Measurement of Intensity, and Damage Produced. *J. H. Hagenguth, T. W. Liao,* General Electric Company

52-106. Investigation of Radio Noise as it Pertains to the Design of High-Voltage Transmission Lines. *H. L. Rorden, R. S. Gens,* Bonneville Power Administration

52-107. Lightning Protection in Extra-High-Voltage Stations—Analysis, Anacom Study, and Results. *I. W. Gross,* American Gas and Electric Corporation; *T. J. Bliss, J. K. Dillard,* Westinghouse Electric Corporation

2:00 p.m. Insulation

52-57. Functional Evaluation of Motor Insulation Systems. *G. A. Cypher, R. Harrington,* General Electric Company

52-58. Aging of Small Motor Insulation. *K. N. Mathes,* General Electric Company

52-59. Diagnoses of A-C Generator Insulation Condition by Nondestructive Tests. *A. W. W. Cameron,* The Hydro-Electric Power Commission of Ontario

CP. The Re-examination of Insulation Temperature Standards.** *G. L. Moses,* Westinghouse Electric Corporation

2:00 p.m. Conference on Fundamental Processes in Gas Discharge Tubes

CP. Physics of Gas Discharges.** *S. C. Brown,* Massachusetts Institute of Technology

CP. Drift Velocities of Charged Particles in Gases.** *J. A. Hornbeck,* Bell Telephone Laboratories, Inc.

CP. The Electron-Ion Recombination Process in Gases.** *S. Borowitz,* New York University

CP. Studies of Hot-Cathode Arcs and Their Engineering Consequences.** *L. Malter,* Radio Corporation of America

2:00 p.m. Color Tubes for Television

CP. A Three-Gun Shadow Mask Color Kinescope.** *D. W. Epstein,* RCA Laboratories

CP. Color Phosphors for Television.** *A. Steadman,* Allen B. Du Mont Laboratories, Inc.

CP. The Chromatron—A Single or Multigun Cathode-Ray Tube.** *Robert Dressler,* Chromatic Television Laboratories, Inc.

CP. Colorimetry in Television.** *F. J. Bingley,* Philco Corporation

2:00 p.m. Education

CP. The Objectives of Graduate Engineering Education—An Employer's View.** *William Oncken, Jr.,* Bureau of Ordnance

CP. Objectives of Graduate Education as Seen by the Public Utility.** *E. R. Gaty,* Philadelphia Electric Company

CP. Specific Objectives of Electrical Engineering Curricula.** *E. A. Walker,* Pennsylvania State College

52-9. A Water Rheostat Using Untreated Water. *J. F. Engle,* Oregon State College. Presentation by title only for discussion

2:00 p.m. System Engineering

52-12. Evaluation of Capacity Differences in the Economic Comparison of Alternative Facilities. *P. H. Jeynes,* Public Service Electric and Gas Company

52-61. Investment Costs for Use in the Economic Comparison of Alternative Facilities. *F. L. Lawton,* Aluminum Laboratories, Ltd. Presentation by title only for discussion

CP. Current Expansion, with ECA Sponsorship, of Italy's Thermoelectric Generating Capacity.** *Fremont Felix,* International General Electric Company

52-62. A Power System Analogue and Network Computer. *E. A. Baldini, A. P. Fugill,* The Detroit Edison Company

52-14. Calculating Machine Simplifies Power Plant Performance Calculations. *E. Daniele, L. J. Parsons, G. R. Baiter,* Consolidated Edison Company of N. Y., Inc.

52-63—ACO.* Planning a Metropolitan Transmission and Subtransmission System. *D. C. Vaughan,* Potomac Electric Power Company

2:00 p.m. New Techniques in Facsimile

CP. Some of the Aspects of High-Speed Facsimile Design.** *M. Alden,* Alden Products Company

52-103. A High-Speed Direct-Scanning Facsimile System. *C. R. Deibert, F. T. Turner, R. H. Snider,* The Western Union Telegraph Company

CP. A High-Speed Facsimile Recorder.** *D. M. Zabriskie,* Western Union Telegraph Company

CP. A High-Speed Facsimile Transmitter.** *L. G. Pollard,* Western Union Telegraph Company

CP. An Improved Desk-Fax Transceiver.** *G. H. Ridings, R. J. Wise,* Western Union Telegraph Company

Thursday, January 24

9:30 a.m. Conference on Sleet Melting Practices

CP. 35 Years Experience Combating Sleet Accumulations.** *A. N. Shealy, K. L. Althouse, R. N. Youtz*

CP. Sleet Thawing Practices on New England Electric System.** *C. P. Corey, H. R. Selfridge, H. R. Tomlinson*

CP. Sleet Melting Practices on Niagara Mohawk System.** *H. B. Smith, W. D. Wilder*

CP. Sleet Melting on the American Gas and Electric System.** *S. C. Bartlett, C. A. Imburgia, G. H. McDaniel*

CP. The Detroit Edison Company Method of Deicing Its 120-Kv Lines.** *D. D. Chase*

CP. Ice Melting and Prevention Practices on Transmission Lines.** *V. L. Davies, L. C. St. Pierre*

9:30 a.m. Electric Couplings

52-64. Magnetic Revolving Field Couplings. *Giovanni Silva,* Compagnia Nazionale Imprese Elettriche

52-65. Performance Calculations on Electric Couplings. *P. H. Trickey,* Vickers, Inc.

CP. Reluctance-Type Magnetic Couplings.** *F. W. Suhr,* General Electric Company

CP. Magnetic Automotive Fan Drives.** *R. L. Jaeschke,* Eaton Manufacturing Company

CP. New Uses for Magnetic Friction Couplings.** *J. A. Mason*

9:30 a.m. Permanent Magnets

CP. Introduction to Permanent Magnets.** *W. E. Ruder,* General Electric Company

CP. Present Problems in the Production of Permanent Magnets.** *A. D. Plamondon, Jr.,* Indiana Steel Products Company

CP. Some Theoretical Aspects of Iron Powder Magnets.** *B. Kopelman,* Sylvania Electric Products, Inc.

CP. A New Permanent Magnet of Non-Strategic Material.** *F. G. Brockman,* Philips Laboratories

CP. Magnetic Structures of Alnico 5.** *E. A. Nesbitt,* Bell Telephone Laboratories, Inc.

CP. Permanent Magnetism of Ordered Structures.** *D. L. Martin, A. H. Geisler,* General Electric Company

9:30 a.m. Electron Tubes

52-66. Tubes for Dielectric Heating at 915 Megacycles. *R. B. Nelson,* General Electric Research Laboratory. Presentation by title only for discussion

CP. A New Rectifier Tube for Extremely High Power and Voltage Levels.** *T. H. Rogers,* Machlett Laboratories, Inc.

CP. High-Power Industrial Vacuum Tubes with Thoriated Tungsten Filaments.** *R. B. Ayer*

CP. Electron Tube Experience in Computing Equipment.** *J. A. Goetz, A. W. Brooke*

CP. The Influence of a Transverse Magnetic Field on an Unconfined Glow Discharge.** *W. D. McGee, W. G. Dow,* University of Michigan

9:30 p.m. Wire and Radio Telegraph Systems

CP. A Carrier Telegraph System for Short-Haul Applications.** *J. L. Hysko, W. T. Rea, L. C. Roberts*

CP. Recent Developments in Multiplex Radio Telegraphy.** *C. Buff*

CP. RCA Electronic Time Division Multiplex Equipment.** *A. Kahn, E. R. Shank*

52-75. Characteristic Impedance of Rectangular Coaxial Transmission Lines. *C. F. Miller,* The Johns Hopkins University; *Y. A. Omar,* Ports and Lighthouses Administration, Alexandria, Egypt

9:30 a.m. Electrical Applications in Pipe-Line Transportation

CP. Development of Pipe Lines.** *H. H. Anderson,* Shell Pipe Line Corporation

CP. Construction of the Ozark Pipe Line.** Technicolor-sound Film. Shell Pipe Line Corporation

CP. Electrical Design of Pipe-Line Pumping Stations for Safety Under Hazardous Atmospheric Conditions.** *M. A. Hyde,* Westinghouse Electric Corporation

CP. Centralized Control of Oil Pipe-Line Pumping Stations.** *C. B. Lester,* Mid-Valley Pipeline Company

9:30 a.m. Electric Heating

52-68. Bus Bar Design for High-Frequency Induction Heating. *J. W. Williamson,* The Ohio Crankshaft Company

CP. Characteristics of Single-Conductor Electric Cable at High Frequency.** *J. T. Sabol,* The Ohio Crankshaft Company

52-4. Induction Preheating of Electrolytic Tin Plate for Flow Brightening with High-Frequency Rotating Equipment. *W. T. Thomas,* General Electric Company. Presentation by title only for discussion

9:30 a.m. Digital Computers—New Storage Developments and Application of Transistors

CP. Three-Dimensional Magnetic Storage.** *J. W. Forrester,* Massachusetts Institute of Technology

CP. Ferroelectric Materials as Storage Elements for Digital Computers and Switching Systems.** *J. R. Anderson,* Bell Telephone Laboratories, Inc.

CP. An Improved Cathode-Ray Tube for Application in Williams Memory Systems.** *W. E. Mutter,* International Business Machines Corporation

CP. Catalogue of Digital Computer Designs.** *J. H. Felker,* Bell Telephone Laboratories, Inc.

2:00 p.m. Transmission and Distribution

52-6. Report of Joint AIEE-Edison Electric Institute Subject Committee on Line Outages

CP. Recovery Voltage Characteristics of Distribution Circuits.** *General Systems Subcommittee Report*

52-108. Guides for Short-Time 60-Cycle Overvoltage Operation of Power Capacitors. *Working Group of the Capacitor Subcommittee*

52-109. General Circuit Constants—Their Formation and Use. *R. D. Goodrich, Jr.,* Bureau of Reclamation

2:00 p.m. D-C Machinery

52-70—ACO.* A Simple, Effective Method of Representing the Load Current of a D-C Machine. *G. L. Hall,* General Electric Company

52-71. Rate of Rise of Short-Circuit Current of D-C Motors and Generators. *Subcommittee on D-C Machinery.* Presentation by title only for discussion

52-72. Commutation of Large D-C Motors and Generators. *T. M. Linville, G. M. Rosenberry,* General Electric Company

52-73—ACO.* Test Code for Carbon Brushes. *Joint Subcommittee on Carbon Brushes.* Presentation by W. W. Walker

CP. Contact Thermocouple for Measuring Commutator Temperatures.** *A. T. McClinton,* Naval Research Laboratory

52-74. Increased Losses in a D-C Motor When Operated From Grid-Controlled Rectifiers. *C. R. Reiter,* Shell Oil Company; *C. R. Ammerman,* The Pennsylvania State College

2:00 p.m. High-Permeability Magnetic Materials

CP. Dynamic Hysteresis Loops.** *H. Lord*, General Electric Company

CP. Mathematical Description of Core Losses.** *F. H. Richardson*, Westinghouse Electric Corporation; *J. W. Hale*, Allegheny Ludlum Research Laboratory

CP. Problems in the Application of Oriented Nickel-Iron Alloys.** *A. C. Beiler*, Westinghouse Electric Corporation

CP. Magnetic Properties of Ferrite Materials.** *Frank Gelbard, H. A. Goldsmith*, General Ceramics and Steatite Corporation

2:00 p.m. Mobile Radio Systems

CP. Lightning Protection of Base Stations in the Mobile Radio Service.** *Report by Committee on Radio Communications Systems*

52-67—ACO.* A Radio Dispatching System for Large Taxicab Fleet Operation. *A. R. Vallarino, S. W. Lewinter*, Federal Telecommunication Laboratories, Inc.

CP. Radio Communication Equipment AN/GRC-3 through 8.** *J. H. Durrer, David Talley*

2:00 a.m. Electrical Applications in Pipe-Line Transportation

CP. Automatic Control of Gas Turbines for Natural Gas Pipe-Line Pumping.** *C. R. Ingemanson, Arne Loft, H. J. Wilt*, General Electric Company

CP. Remote Operation of Pipe-Line Stations by Supervisory Control.** *Clyde Hepler*, Pan American Pipe Line Company; *W. A. Derr, L. B. Eddy*, Westinghouse Electric Corporation

CP. New Electric Pressure Instrumentation on Petroleum Pipe Lines.** *M. J. Dabney*, Plantation Pipeline Company

CP. Microwave Radio for Pipe-Line Use.** *C. D. Campbell*, Humble Pipe Line Company

2:00 p.m. Symposium on Heating Application Data

2:00 p.m. Small Digital Computers

CP. The USAF-Fairchild Computer.** *J. J. Stone*, Oak Ridge National Laboratory

CP. The MADDIDA—Its Operation and Mathematics.** *C. B. Dennis*, Northrup Aircraft Corporation

CP. The JAINCOMP Computer.** *D. H. Jacobs*, Jacobs Instrument Corporation

CP. The CADAC.** *W. E. Dobbins*, Computer Research Corporation

2:00 p.m. Conference on Energy Sources

CP. Magnetic Storms.** *O. B. Jacobs, J. J. Gilbert*

CP. Sunspots and Planetary Effects Upon Radio Signals.** *J. H. Nelson*

Friday, January 25

9:30 a.m. Transformers

52-76. The Impulse Testing of Low-Voltage High-Kilovolt-Ampere Transformer Windings. *L. C. Aicher*, Allis-Chalmers Manufacturing Company

52-77. The Impulse Generator and Its Uses. *J. H. Chiles, Jr., W. L. Teague*, Westinghouse Electric Corporation

CP. Impulse Testing of Power Transformers.** *J. R. Meador, J. H. Hagenguth*, General Electric Company

52-78. Gaseous Insulation for High-Voltage Transformers. *G. Camilli, R. E. Plump*, General Electric Company; *G. S. Gordon*, Skillman, N. J.

52-79. Recent Improvements in Theory and Practice of Vacuum Plastic-Filled Insulation for Voltage Transformers. *E. C. Wentz, F. B. Colby*, Westinghouse Electric Corporation

9:30 a.m. Station and Control Cable Symposium

CP. Economy and Reliability of Control Cable Installations.** *U. S. Sherman*, Philadelphia Electric Company

CP. Auxiliary Power and Control Cables.** *E. E. McIlveen, R. C. Waldron*, The Okonite Company

CP. Airport Cable Installations.** *C. R. Johnson*, Port of N. Y. Authority

CP. Effect of Environment and D-C Potentials on Non-Metallic Sheath Control Cables.** *E. W. Davis*, Simplex Wire and Cable Company

9:30 a.m. Transmission and Distribution

52-110. Power System Stability Criterions for Design. *W. A. Morgan*, Bureau of Reclamation

CP. An Analogue of a Synchronous Machine for Use in Transient Stability Studies.** *J. E. Van Ness*, Northwestern University

52-111. Tensorial Analysis of Integrated Transmission Systems, Part II—Off Nominal Turn Ratios. *Gabriel Kron*, General Electric Company

52-112. Evaluation of Methods of Co-ordinating Incremental Fuel Costs and Incremental Transmission Losses. *L. K. Kirchmayer*, General Electric Company; *G. W. Stagg*, American Gas and Electric Service Corporation

9:30 a.m. Materials

CP. Report of the Materials Subcommittee of the Magnetic Amplifier Committee**

CP. Magnetic Properties of Ultra-Thin Magnetic Alloys—Manufacture.** *M. F. Littmann*

CP. Magnetic Properties of Ultra-Thin Magnetic Alloys—Application.** *J. G. Miles*

52-26. The Effect of Core Materials on Magnetic Amplifier Circuits. *L. J. Johnson*, Naval Research Laboratory

9:30 a.m. Industrial Power Systems

52-80. Electric Power Supply for a Large Chemical Plant. *A. C. Friel*, The Dow Chemical Company; *J. P. Smith*, General Electric Company

CP. Electrical Systems in the Port Authority Bus Terminal.** *W. Henschel, H. W. Wenson, Jr.*, Port of N. Y. Authority

CP. Electrical Systems for the United Nations Headquarters.** *F. B. Graham*, Syska and Hennessy, Inc.

9:30 a.m. Feedback Control Systems

52-81. The Writing of Closed-Loop Control System Transfer Function by Inspection. *J. B. Flanagan*, Sperry Gyroscope Company; *H. S. Kirschbaum*, Ohio State University

52-82. Synthesis of Closed-Loop Systems Using Curvilinear Squares to Predict Root Location. *D. W. Russell*, Arnold Engineering Development Center; *C. H. Weaver*, The University of Tennessee

CP. Additions to the Stability Theory and Design of Servomechanisms.** *J. F. Koenig*

9:30 a.m. Single-Phase and Fractional Horsepower

52-48. Toward An Accurate Evaluation of Single-Phase Induction-Motor Constants. *F. W. Suhr*, General Electric Company

52-49. A Quadrature-Base-Shift Voltage Transformer Device and Its Applications. *R. L. Hupp, F. W. Suhr*, General Electric Company

52-50. Moneca—A New Network Calculator for Motor Performance Calculations. *C. G. Veinott*, Westinghouse Electric Corporation

52-86—ACO.* An Equivalent Cantilever Circuit for Polyphase Induction Motor for Practical Calculations. *T. C. Tsao*, Consolidated Edison Company of N. Y., Inc.; *N. F. Tsang*, University of Arkansas

2:00 p.m. Transformers

52-87. Field Tests on Power Transformers Equipped with Thermosiphon Oil Filters. *E. W. Tipton*, Westinghouse Electric Corporation

52-88. Controlled Temperature and Insulation Protection in the Operation of Power Transformers. *W. W. Satterlee*, Westinghouse Electric Corporation

CP. Winding Hot Spot Temperature Equipment for Transformers.** *G. Camilli, A. R. Kimball, H. A. Forhaltz*, General Electric Company

52-89. The Economics of High-Temperature Dry-Type Transformers. *L. C. Whitman*, General Electric Company

52-90. Characteristics of Overlapping Joints in Magnetic Circuits. *T. D. Gordy*, General Electric Company; *H. L. Garbarino*, Armour Research Foundation

52-115. A New Concept of Insulating Oil Life Characteristics. *F. C. Doble*, Doble Engineering Company

2:00 p.m. Insulated Conductors

52-91. A-C Resistance of Pipe-Cable Systems with Segmental Conductors. *AIEE Working Group of Cable Characteristics Subcommittee*

52-92. Auxiliary Power and Control Cables for Steam-Electric Generating Stations. *F. V. Smith, E. G. Norell*, Sargent and Lundy

52-93—ACO.* Generator Lead Practice. *M. J. Lowenberg*, Stone and Webster Engineering Corporation

2:00 p.m. Circuits

52-94. Series-Connected Magnetic Amplifier with Inductive Loading. *T. G. Wilson*, Naval Research Laboratory

52-5. Compensating for the Quiescent Current in Multistage Magnetic Amplifiers. *A. S. FitzGerald*, San Francisco, Calif.

CP. Effects of Leakage of Feedback Rectifiers.** *L. A. Finzi*, Carnegie Institute of Technology

2:00 p.m. Industrial Power Systems and Relays

CP. Power Distribution at New York International Airport.** *C. R. Johnson*, Port of N. Y. Authority; *V. P. Brodsky, A. B. Henderson*, Consolidated Edison Company of N. Y., Inc.

CP. Selection of Protective Device Settings for Industrial Plants.** *F. P. Brightman*, General Electric Company

CP. Some Considerations of the Relay Protection Problem of Industrial Distribution Systems.** *W. A. Frankenfield*, The Detroit Edison Company

2:00 p.m. Symposium on Germanium Rectifiers and Transistors

CP. A-B-C of Germanium.** *J. P. Jordan*, General Electric Company

CP. Conduction Properties of Germanium Single Crystals.** *W. C. Dunlap, Jr.*, General Electric Company

CP. The N-P-N Junction Transistor.** *J. A. Morton*, Bell Telephone Laboratories, Inc.

CP. Circuits for Junction Transistors.** *R. L. Wallace*, Bell Telephone Laboratories, Inc.

CP. Recovery of Germanium from Factory Waste.** *V. Ozerow*, General Electric Company

CP. A New Germanium Power Rectifier.** *F. J. Lingel*, General Electric Company

2:00 p.m. Feedback Control Systems

52-95—ACO.* A New Parallel-Type Compensation Network. *G. F. Warnke, V. H. Disney*, Armour Research Foundation

CP. Stabilization Templates for Servomechanisms.** *O. J. M. Smith*, University of California

52-8. An Electronic Apparatus for the Study of the Human Operator in a 1-Dimensional, Closed-Loop, Continuous Pursuit Task. *C. E. Warren, P. M. Fitts, J. R. Clark*, Ohio State University

CP. The Figure of Merit of D-C Rotating Power Amplifiers.** *J. T. Carleton*, Westinghouse Electric Corporation

2:00 p.m. A-C Network Calculator Designs and Experience

52-19. A New Principle is Employed for 60-Cycle A-C Network Analyzers. *E. B. Phillips*, University of Kansas

CP. Operating Experience with a 10-Kc Network Analyzer.** *W. B. Boast*, Iowa State College

CP. Design Improvements in the 10,000-Cycle Network Analyzer.** *J. D. Ryder*, University of Illinois

52-113. A Compact, Inexpensive A-C Network Analyzer. *E. W. Kimbark*, Instituto Tecnológico de Aeronáutica; *J. H. Starr*, LaGrange, Ill.; *J. E. Van Ness*, Northwestern University

(*Continued from page 87*)

Steinway and Sons, New York, N. Y. (Tuesday afternoon, January 22). A famous institution in the world of music will permit a limited number of AIEE members to visit the home of the Steinway piano and see skilled craftsmen assembling and finishing world-renown instruments. This unusual trip will be found most interesting by those appreciating the work of a master artisan.

International Business Machines Company, New York, N. Y. (Tuesday afternoon, January 22, and Thursday morning, January 24). The International Business Machines Company, a pioneer in the manufacture of labor-saving devices, will demonstrate and explain the operation of their Selective Sequence Electronic Calculator. This calculator has received considerable publicity in technical journals recently. It combines the speed of the electric circuit with the memory capacity of 400,000 digits for obtaining the answer to many complex problems of science and industry. In addition, numerous other electronic devices will be exhibited and their operation explained by technical personnel.

Westinghouse Electric Corporation, Hillsdale, N. J. (Wednesday morning, January 23). To provide prompt and efficient service for its customers in this area, the Westinghouse Electric Corporation recently completed a modern plant at Hillsdale, N. J., for the manufacture and assembly of switchboards and many items of switchgear. Facilities for the maintenance and repair of practically all the power equipment of Westinghouse are found at this plant, in addition to the many manufacturing processes in progress there.

United States Signal Corps Photographic Center, New York, N. Y. (Wednesday morning, January 23). During World War II, expansion of the photographic function of the Signal Corps necessitated a larger plant and new facilities to quickly carry out its program. To this end it acquired the Famous Players-Lasky Studio in New York. This studio is now used for training personnel and for the practical application of photography to Signal Corps activities. The present staff is composed of approximately 300 officers and enlisted men and 1,000 civilian employees. Here scripts are written, casting performed, stages set, and film exposed, developed, edited, and synchronized with sound.

Harbor Radar Installation of the Port of New York Authority, Fort Wadsworth, Staten Island, N. Y. (Wednesday morning, January 23). A limited number of AIEE members will be permitted to view the equipment and attend a demonstration of the operation of the radar installation installed for the identification and control of ship traffic in New York Harbor.

New York Curb Exchange, New York, N. Y. (Wednesday afternoon, January 23). This nationally known financial institution will give AIEE visitors an opportunity to see the Exchange in operation and to hear an explanation of its functions. The intricate communications system, the elaborate lighting, the air-conditioning system, and other features of the Exchange also will be seen on this trip.

Bell Telephone Laboratories, Murray Hill, N. J. (Wednesday afternoon, January 23). Research in all fields of basic science is conducted at the Bell Telephone Laboratories, Inc. The program proposed for this trip is a visit to the Microwave Laboratories, the Digital Computer, the Piezoelectric Crystal Growing Laboratory, the Metallurgical Laboratories, the Free Space Room, the New Telephone Instrument Laboratories, and demonstrations of Acoustic and Microwave lens and of the Carrier Telephone System.

Sewaren Generating Station, Sewaren, N. J. (Wednesday afternoon, January 23). Sewaren Generating Station of Public Service Electric and Gas Company, first placed in service in November 1948, now contains four turbine-generators and four semioutdoor boilers having an aggregate capacity of 455,000 kw. The fourth unit, placed in operation last summer, is a 125,000-kw reheat unit operating on 1,500 pounds per square inch, 1,050 degrees Fahrenheit initial steam conditions and 1,000 degrees Fahrenheit reheat temperature. The station is arranged to burn bituminous coal, fuel oil, and natural gas. The outdoor substation facilities include 132-kv and 26-kv transformers. Station auxiliaries are supplied from the auxiliary generator of each unit, with station power transformers available for emergency backup and starting.

New Port of New York Authority Bus Terminal, New York, N. Y. (Thursday morning, January 24). The most recent addition to the transportation facilities of New York City is the world's largest and most heavily used bus terminal designed for handling both commuter and long-distance travel. The inspection of the terminal will include the ventilating system, escalators, lighting, power distribution, and other points of interest in this unique building.

Metropolitan Museum of Art, New York, N. Y. (Thursday afternoon, January 24). Although this trip was arranged primarily for members to inspect features of the Special Lighting Research conducted by the Metropolitan Museum of Art, visitors

The production crew and cast are shown in a desert scene from an Army training film, "General Effects of Heat on Man." This film was shot entirely at the studios of the Signal Corps Photographic Center, another inspection trip for those attending the Winter Meeting

Future AIEE Meetings

AIEE Conference on Electronic Instrumentation and Nucleonics in Medicine (*page 94*)
Hotel Commodore, New York, N. Y.
January 7–8, 1952

Winter General Meeting
Hotel Statler, New York, N. Y.
January 21–25, 1952
(*Final date for submitting papers—closed*)

Joint AIEE-IRE-AEC-NBS Scintillation Counter Symposium (*page 96*)
Bureau of Standards, Washington, D. C.
January 29–30, 1952

AIEE Conference on Induction and Dielectric Heating (*page 96*)
Carter Hotel, Cleveland, Ohio
February 19–20, 1952

South West District Meeting
Jefferson Hotel, St. Louis, Mo.
April 15–17, 1952
(*Final date for submitting papers—January 16*)

North Eastern District Meeting
Binghamton, N. Y.
April 30–May 2, 1952
(*Final date for submitting papers—January 31*)

Joint AIEE-IRE-RTMA Conference on Progress in Quality of Electronic Components
Washington, D. C.
May 5–7, 1952

AIEE Conference on Electronic Converter Applications and Tubes (*page 96*)
William Penn Hotel, Pittsburgh, Pa.
May 19–20, 1952

Summer General Meeting
Hotel Nicollet, Minneapolis, Minn.
June 23–27, 1952
(*Final date for submitting papers—March 25*)

Pacific General Meeting
Phoenix, Ariz.
August 19–22, 1952
(*Final date for submitting papers—May 21*)

AIEE Participation in Centennial of Engineering
Congress Hotel, Chicago, Ill.
September 10–12, 1952

Fall General Meeting
New Orleans, La.
October 13–17, 1952
(*Final date for submitting papers—June 13*)

Middle Eastern District Meeting
Commodore Perry Hotel, Toledo, Ohio
October 28–30, 1952
(*Final date for submitting papers—July 30*)

may take this opportunity to view and admire the many notable works of art on exhibit.

The Okonite Company, Passaic, N. J. (Thursday afternoon, January 24). On this trip to the largest of the three Okonite factories, members will have an opportuniy to see modern methods of manufacturing insulated electric cable of all types and designs. This factory is especially interesting because cables for specific conditions and of individual designs are fabricated here. All production steps from drawing of the wire to the final sheathing of the cable will be demonstrated.

Dow Corning Exposition—Governor Clinton Hotel, New York, N. Y. (Daily 10:00 a.m. to 8:00 p.m., January 21 through January 25). This is a special display of hundreds of component parts and assemblies, and over 20 working models designed to indicate the properties that distinguish silicones from other materials. The ability to withstand extreme temperatures, moisture, voltages, and other operating conditions is demonstrated by this extraordinary new material in the many exhibits to be seen.

THEATER TICKETS

It is expected that tickets for the following shows will be available to out-of-town AIEE members during the week of the meeting. Prices listed are for orchestra seats Monday, January 21, through Thursday, January 24, evenings:

Affairs of State	$4.80
Call Me Madam	7.20
Guys and Dolls	6.60
South Pacific	6.00
The King and I	8.40*
Two on the Aisle	6.00

* These tickets are not available to us from the box office and must be obtained through brokers. The price shown includes broker's fee. It may become necessary to classify additional shows in this category.

Requests should include checks payable to "American Institute of Electrical Engineers," first and second choice of both name and date of show, and should be sent to Theater Ticket Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Preference will be given to requests for seats in blocks of pairs and the committee reserves the right to reduce requests to sell-out shows to two tickets and will refund all money which may be received for unsatisfied requests.

HOTEL RESERVATIONS

Blocks of rooms have been set aside at the Hotel Statler (meeting headquarters) and nearby hotels for members and guest attending. To be sure of hotel accommodations, reservations should be made prior to January 10, and sent directly to the hotel of choice, and to only one hotel. Mention AIEE in your request and send a copy to Mr. W. G. Vieth, Vice-Chairman, Hotel Accommodations Committee, c/o Western Union Telegraph Company, 60 Hudson Street, New York 13, N. Y. A second and third choice should be noted on this copy. If the accommodations are not available at the hotel requested, the Hotel Accommodations Committee will transfer the request to one of the other hotels.

Hotel rooms have been reserved at the following hotels, and all rates are subject to a 5 per cent New York City hotel room tax.

Hotel Statler (meeting headquarters)
7th Avenue, 32nd to 33rd Streets

Single room with bath	$ 5.00 to $ 8.50
Double room, double bed	8.00 to 10.50
Double room, twin beds	9.00 to 15.00
Parlor suites	22.00 to 24.00

Hotel Governor Clinton, 7th Avenue at 31st Street

Single room with bath	$ 5.00 to $ 7.00
Double room, double bed	8.00 to 9.50
Double room, twin beds	9.00 to 11.00

Hotel McAlpin, Broadway and 34th Street

Single room with bath	$ 5.00 to $ 9.00
Double room, double bed	8.00 to 12.00
Double room, twin beds	9.00 to 13.00

Hotel New Yorker, 34th Street and 8th Avenue

Single room, tub and shower	$ 5.00 to $ 8.00
Double room, double bed	8.00 to 13.00
Double room, twin beds	9.50 to 14.00

Hotel Martinique, Broadway and 32nd Street

Single room with bath	$ 4.00 to $ 6.00
Double room, double bed	6.50 to 10.00
Double room, twin beds	7.50 to 10.00

Hotel Commodore, 42nd Street at Lexington Avenue

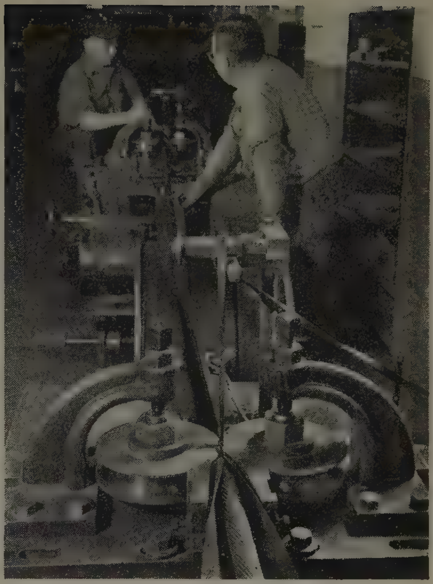
Single room with bath	$ 5.50 to $10.00
Double room, double bed	9.00 to 11.00
Double room, twin beds	10.00 to 13.00

Hotel Roosevelt, Madison Avenue at 45th Street

Single room with bath	$ 6.50 to $10.00
Double room, double bed	12.50 to 16.00
Double room, twin beds	13.50 to 17.00

DINNER-DANCE

The dinner-dance promises to be the usual outstanding social event for the convention delegates and their ladies. It will be held Thursday, January 24, in the main ballroom of the Hotel Statler. Formal dress is requested. Music and general arrangements will be the same as those which proved so enjoyable last year. Begin to plan for your table of ten for this popular event of the Winter General Meeting social activities. Reservations at $12.00 per plate will be accepted by the Dinner-Dance Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y. Checks should be made payable to "Special Account, Secretary, AIEE." The committee is under the chairmanship of J. G. Derse.


Insulation is being applied by the multiple strip process at the Okonite Company in Passaic, N. J.; one of the inspection trips will be to this company

SMOKER

The Smoker Committee, under the chairmanship of D. M. Quick, announces that the Smoker will be held at the Hotel Commodore on Tuesday evening, January 22. Reservations should be sent to the Smoker Committee, AIEE Headquarters, 33 West 39th Street, New York 18, N. Y., at an early date. Tables for ten persons will be available and the price of tickets will be $9.00 per person. Checks should be made payable to "Special Account, Secretary, AIEE." Reservations received after January 8 will not be honored.

ETA KAPPA NU AWARD DINNER

One of the highlights of the Winter General Meeting will be the Annual Recognition Dinner of the Eta Kappa Nu Association, electrical engineering honor society, to be held Monday evening, January 21. At this dinner, the Eta Kappa Nu Plaque designating the Most Outstanding Young Electrical Engineer for 1951 will be awarded and men receiving honorable mention cited.

The Recognition was created to emphasize among electrical engineers that their service to mankind is manifested not only by achievements in purely technical pursuits but also by contributions to their profession, community, and church, and by cultural attainments. This year's winners were selected by a Jury of Award consisting of S. H. Mortensen, Chief Electrical Engineer, Allis-Chalmers Manufacturing Company, Dr. J. O. Perrine, former editor of the *Bell System Technical Journal*, Frank E. Sanford, Assistant Chief Engineer, Commonwealth

During an inspection trip to the International Business Machines Company the IBM Selective Sequence Electronic Calculator will be seen. This combines for the first time electronic speed, vast memory capacity, and flexible, convenient sequencing facilities

Services, Inc., Philip Sporn, President, American Gas and Electric Service Corporation, Dean Eric A. Walker, School of Engineering, the Pennsylvania State College, and Dean Ovid W. Eshbach, the Technological Institute, Northwestern University, President of Eta Kappa Nu (EKN).

Information concerning place and time of the dinner or any additional details can be obtained by contacting Mr. Elies Elvove, Chairman, EKN Award Organization Committee, c/o McConnaughy and Elvove, 22 East 17th Street, New York, N. Y.

LADIES' ENTERTAINMENT

The Ladies' Entertainment Committee, under the chairmanship of Mrs. R. F. Brower, has arranged an interesting program for the week of January 21. A Get-Acquainted Tea will be held on Monday afternoon, January 21, in the Ladies' Headquarters at the Hotel Statler. Arrangements can be made to visit the Hayden Planetarium in the evening. On Tuesday evening there will be cocktails, dinner, and entertainment at the Hotel Statler. Tickets will be $5.00 per person and reservations should be made as early as possible with the Ladies' Committee. The deadline for reservations is Tuesday morning, January 22. On Wednesday there will be a conducted tour of the city, and on Thursday afternoon there will be a luncheon and fashion show at Sherry's and there will be door prizes. Broadcast and theater tickets will be available during the week.

WINTER GENERAL MEETING COMMITTEE

The members of the 1952 Winter General Meeting Committee are: G. J. Lowell, *Chairman;* C. T. Hatcher, *Vice-Chairman;* J. J. Anderson, *Secretary;* W. J. Barrett, *Budget Co-ordinator;* C. S. Purnell, *Vice-President, District 3, AIEE;* M. M. Brandon, *Technical Program;* J. P. Neubauer, D. W. Taylor, J. D. Tebo, D. T. Braymer, *General Session;* R. T. Weil, *Monitors;* G. T. Minasian, J. B. Harris, Jr., *Publicity;* C. N. Metcalf, *Hotel Accommodations;* E. R. Thomas, *Registration;* D. M. Quick, *Smoker;* Mrs. R. F. Brower, *Ladies' Entertainment;* J. G. Derse, *Dinner-Dance;* F. P. Josslon, *Inspection Trips;* J. G. Aldworth, *Theater-Radio.*

Fourth Electronic Instrumentation Conference Planned for Jan. 7–8

The fourth conference on Electronic Instrumentation and Nucleonics in Medicine will be held January 7 and 8 in the Ballroom of the Hotel Commodore, New York, N. Y. Chief sponsoring committee is the newly formed Committee on Electrical Techniques in Medicine and Biology, an outgrowth of the earlier joint activities of the Committees on Nucleonics, Electronics, Instruments and Measurements, and Therapeutics.

The first day of the conference will be devoted to nucleonic applications to medicine, including X rays, gamma rays, and tracers. The second day concerns electric circuit theory in the study of the circulatory and respiratory systems, and electronic techniques in anesthesia.

Highlighting the conference will be a demonstration lecture on "Television in Medicine and Biology" by Dr. V. K. Zworykin and Mr. L. E. Flory, of the Radio Corporation of America (RCA) David Sarnoff Research Center, Princeton, N. J. This article is published in full on pages 40–45 of this issue. The lecture will be preceded by an informal dinner Monday at 6:30 p.m. The audience will see on a television screen what usually is seen through a microscope, and in addition will be shown how ultraviolet light rays are used to great advantage in medical microscopy.

While it is hoped that the papers presented will eventually be published, they will not be available at the time of the conference. However, each registrant will receive an abstract of the papers at no additional charge.

HOTEL RESERVATIONS

The Hotel Commodore has been selected for the conference this year. Its location adjacent to Grand Central Terminal, and its easy access to local transportation, as well as its excellent facilities for such a meeting, make it an ideal place for the conference. Rooms have been allotted for those attending the conference, and accommodations may be secured directly from the Hotel Commodore.

CONFERENCE REGISTRATION

The Registration Desk will be located in the Ballroom Foyer of the Hotel Commodore and will be open at 9:00 a.m. each morning of the conference. The registration fee is $3.50 which includes all sessions and the lecture-demonstration Monday evening.

An informal dinner preceding the lecture-demonstration on Monday evening will provide an opportunity for friends and acquaintances to make and renew friendships. Cost of this dinner will be $5.00.

COMMITTEE MEMBERS

The chairmen of the committees making arrangements for this conference are: J. D. Tebo, *Planning;* S. R. Warren, Jr., *Technical Program;* C. L. Shackleford, *Local Arrangements;* H. J. Carlin, *Registration;* J. S. Smith, *Finance;* and G. C. B. Rowe, *Publicity.*

Technical Program

Conference on Electronic Instrumentation and Nucleonics in Medicine
New York City, N. Y., January 7-8, 1952

Monday, January 7

9:30 a.m.

Presiding: G. Failla, Radiological Research Laboratory, Columbia University

Development of the Phosphor-Phototube Combination as a Reliable Radiation Detector. *D. Cole, P. A. Duffy, M. E. Hays, W. S. Lusby, E. I. Webb,* Westinghouse Electric Corporation

A Unique Instrument for the Precise Measurement of Gamma Radiation. *Philip E. Ohmart,* Ohmart Corporation

Fluorescent Crystal Counting in Medical Tracer Research. *Hal O. Anger,* Donner Laboratory, University of California

A Cobalt 60 Irradiator for Teletherapy. *E. Dale Trout, John Vlach,* General Electric Company

Scintillation Counting for Brain Tumor Localization. *Dr. Bertram Selverstone,* Department of Neurosurgery, Tufts College Medical School; *Waldron S. Macdonald, William E. C. Eustis,* W. S. Macdonald Company

2:00 p.m.

Presiding: H. D. Moreland, Westinghouse Electric Corporation

Production of Monochromatic X-Radiation for Microradiography by Excitation of Fluorescent Characteristic Radiation. *T. H. Rogers,* Machlett Laboratories, Inc.

Calorimetric Determination of the Energy of X-Ray Beams. *John H. Laughlin,* College of Medicine, University of Illinois

High Energy Electron and X-Ray Beams from the 80 mev Synchrotron. *H. C. Pollock,* General Electric Company

A Fluoroscopic Screen Intensifier for Medical Use. *Dr. Russell H. Morgan,* The Johns Hopkins Medical Institutions; *Ralph E. Sturm,* The Johns Hopkins Medical Institutions

8:00 p.m.

Chairman: G. A. Morton, RCA Laboratories

Television in Medicine and Biology, with demonstration; *Vladimir K. Zworykin, Leslie E. Flory,* RCA Laboratories

Tuesday, January 8

9:30 a.m.

Presiding: Dr. W. A. Geohegan, St. Lukes Hospital

Wave Propagation in the Living Human Artery. *Dr. Milton Landowne,* National Heart Institute and Baltimore City Hospitals

A Mechanical Heart for Artificial Maintenance of the Circulation. *Dr. S. A. Weslowski,* Tufts College Medical School; *Dr. C. Stuart Welch,* New England Center Hospital

Physical Response Requirements of Pressure Transducers for the Reproduction of Physiological Phenomena. *E. H. Wood, Mayo, Clinic*

Analysis of Viscous and Elastic Properties of the Respiratory System by Electric Circuit Theory and Electronic Measurement Techniques. *Dr. Jere Mede* Harvard School of Public Health; *Arthur Miller,* Sanborn Company

2:00 p.m.

Presiding: Ernst Weber, Polytechnic Institute of Brooklyn

The Application of Electrical and Acoustic Impedance Measuring Techniques to Problems of Diathermy. *Herman Schwan,* Department of Physical Medicine, Graduate School of Medicine; *E. L. Carstensen,* Moore School of Electrical Engineering, University of Pennsylvania

A Monitor of Physiological Variables for Anesthesia and Other Uses. *S. R. Gilford,* Electronics Division, National Bureau of Standards

Physiologic Measurements of Interest to the Clinical Anesthesiologist. *Dr. Albert Faulconer,* Mayo Clinic

Instrumentation for the Electronic Control of Anesthesia. *R. G. Bickford,* Mayo Clinic

Regular Meeting of AIEE Board of Directors Held in Cleveland, Ohio

A regular meeting of the Board of Directors of the Institute was held in the Hotel Cleveland, Cleveland, Ohio, October 25, 1951, during the Fall General Meeting.

The minutes of the meeting of the Board of Directors held in Portland, Oreg., on August 23, 1951, were approved.

A resolution in memory of Director Allen G. Dewars, who died on August 26, 1951, was adopted, as follows:

RESOLVED: That, upon behalf of the membership of the American Institute of Electrical Engineers, the Board of Directors hereby expresses regret at the death of Allen G. Dewars, a Vice-President and later a Director of the AIEE from 1950 until his death on August 26, 1951, a Fellow since 1944, and a distinguished active participant in Institute affairs for better than thirty years; and extends sincere sympathy to members of his family.

The following actions of the Executive Committee on membership applications as of September 27, 1951, were reported and confirmed: 13 applicants transferred to the grade of Fellow; 103 applicants transferred and 58 elected to the grade of Member; 306 applicants elected to the grade of Associate Member and one Associate Member reinstated; 71 Student members enrolled.

Recommendations of the Board of Examiners adopted at meetings on September 20 and October 18, 1951, were reported and approved. The following actions were taken upon recommendation of the Board of Examiners: 22 applicants were elected to the grade of Member; 114 applicants were elected to the grade of Associate Member; 5 applicants were elected to the grade of Affiliate; 312 Student members were enrolled.

A report of the Committee on Public Relations of the activities of the committee was presented and accepted with thanks.

FINANCES

Disbursements from general funds were reported by Chairman Barrett of the Finance Committee and approved by the Board, as follows: September, $64,277.90; and October, $99,050.80.

Chairman Barrett of the Finance Committee announced the granting of a loan of $300 for preparation for a Special Conference on Machine Tools which was held in Rockford, Ill., November 14–16, 1951.

A report by Chairman Mark Eldredge of the Committee on Members-for-Life Fund was presented, to the effect that the committee had given further consideration to the possibility of providing for the regular expense allowance for the Student prize winners in all Districts to attend the Summer General Meeting each year instead of those from only five Districts as in the past. The committee had concluded "that the Fund and the income are such that we can adequately and safely meet the expenses for the winners of Student paper prize contests from all Districts." (The Board of Directors, in June, approved in principle a recommendation of the Committee on Student Branches that such provision be made, the Board to appropriate from general funds any amount that might be required in addition to the sum that could be supplied from the Fund.)

A budget for the appropriation year ending September 30, 1952, as recommended by the Finance Committee was submitted by Chairman Barrett and was adopted by the Board.

OTHER BUSINESS

After a discussion of a plan for divisional organization of AIEE technical activities presented by the Committee on Planning and Co-ordination to the October Forum of Technical Committee Chairmen for discussion, the Board appointed Chairman M. D. Hooven of the Committee on Planning and Co-ordination a committee of one to formalize for the Institute Bylaws the present procedure and operation of the technical committees, with recommendations.

Elgin B. Robertson was elected a Director of the Institute for the remainder of the term ending July 31, 1954, of Allen G. Dewars, deceased.

The Board accepted with regret the resignation of John D. Harper as Vice-President, Southern District, because of his removal from the District, and elected Edwin S. Lammers, Jr., of Atlanta, Ga., Vice-President, for the remainder of the term expiring July 31, 1953.

Upon recommendation of the Committee on Constitution and Bylaws, Section 16, transferred from the Constitution to the Bylaws by action of the Board of Directors in January 1951, was amended to read as follows:

"The entrance fees payable on admission to the Institute shall be as follows:

Admission to the grade of Member, fifteen (15) dollars.

Admission to the grade of Associate Member, ten (10) dollars.

Admission to the grade of Affiliate, ten (10) dollars.

"The transfer fee from Affiliate to Associate Member shall be five (5) dollars and from Associate Member to Member five (5) dollars. Persons admitted to the Associate Member grade upon the expiration of their term of Student enrollment shall not be required to pay the entrance fee. Student members of other engineering societies may be similarly admitted to the Associate Member grade under conditions set forth in the Bylaws."

Chairman Purnell of the Sections Committee reported that an agreement had been reached between the Section and District officers concerned regarding the exact territory involved in the transfer, previously authorized by the Board of Directors, of the Lake Charles Subsection from the New Orleans Section and District 4 to the Beaumont Section and District 7. The territory of the Subsection consists of the following parishes in Louisiana: Allen, Jefferson Davis, Cameron, Calcasieu, Beauregard.

The Board authorized the establishment of a Corpus Christi Section from the Corpus Christi Subsection of the South Texas Section, with a territory composed of certain counties in Texas released by the South Texas Section.

A study of prevailing conditions with regard to sports at Summer General Meetings during the past several years was reported, revealing small numbers of competitors in the golf and tennis tournaments, difficulty in procuring the necessary facilities for such tournaments in the usual locations of the meetings, and conflict with the heavy technical programs now favored. The Board therefore voted to discontinue the competitions for the Mershon golf and tennis trophies. These trophies, donated by Past President Ralph D. Mershon, will remain on display at Institute headquarters.

APPOINTMENTS AND REPORTS

Dr. D. D. Ewing was elected a Board representative on the Edison Medal Committee for the remainder of the term, ending July 31, 1953, of Mr. J. D. Harper, who resigned because of his resignation as Vice-President and member of the Board of Directors.

Members of the Board of Directors were selected as members and alternates to represent the Board on the AIEE Nominating Committee, as follows: Members—W. J. Barrett, F. R. Benedict, R. F. Danner, J. R. North, J. C. Strasbourger; Alternates—H. R. Fritz, J. A. McDonald.

Upon invitation, Chairman L. F. Hickernell of the Technical Advisory Committee reported on the activities of that committee, and Chairman K. B. McEachron of the Publication Committee reviewed the present status of activities of his committee.

Past President T. G. LeClair, AIEE representative on the Exploratory Group to Consider Further Unity in the Engineering Profession, reported on a meeting of the group held in New York in September, which was attended by 13 representatives. Agreement was reached that of the four plans for a unity organization which have been under consideration, the Exploratory Group will recommend the necessary changes in the Engineers Joint Council to make it the unity organization; and the secretary, Dr. Harold S. Osborne, was requested to take the lead in the preparation of a plan.

Secretary H. H. Henline was appointed AIEE representative on the Construction Industry Advisory Council in place of Henry A. Lardner, who had declined reappointment.

Certain recommendations adopted at the Conference of Representatives from Engineering Societies in Western Europe and the United States of America, The Hague, September 17–21, 1951, were referred to the Engineers' Council for Professional Development for comments, and another recommendation to the AIEE Publication Committee. President McMillan reported briefly on other aspects of the conference, which he and Secretary Henline had attended as AIEE representatives, in accord with an action by the Board of Directors on April 12, 1951.

Mr. Barrett reported that the Special Task Group on Problems of Salary Stabilization of the Engineers Joint Council (EJC) had completed its work, and a statement over the signature of President Todd of EJC had been sent to the Salary Stabilization Board.

Mr. Hooven, one of the Institute's representatives on the Engineers' Council for

Professional Development (ECPD), reported briefly on the annual meeting of ECPD held in Boston, Mass., October 19–20.

Mr. Davis reported attendance, as AIEE representative, at the Dugald C. Jackson Memorial Service, in Cambridge, Mass., on October 21, a very impressive service.

A report was presented of various matters considered at a meeting of the Executive Committee of District 2. It was understood that several items would be referred to the Committee on Planning and Co-ordination, and one recommendation was referred to the Committee on Transfers.

After a reconsideration of the Board's action on August 23 regarding the supply of Student badges to Student members without charge, as it contained no provision for supplying badges to Students already enrolled, it was voted that any Student member who has renewed at the $5.00 rate may have a plated vest pin or lapel button without charge, upon request.

Present at the meeting were: *President* F. O. McMillan; *Past Presidents* J. F. Fairman, T. G. LeClair; *Vice-Presidents* H. R. Fritz, J. D. Harper, J. A. McDonald, F. W. Norris, J. R. North, C. S. Purnell, J. C. Strasbourger, J. G. Tarboux, W. R. Way; *Directors* W. J. Barrett, F. R. Benedict, R. F. Danner, E. W. Davis, D. D. Ewing, C. W. Fick, A. H. Frampton, N. B. Hinson, M. D. Hooven, Elgin B. Robertson (luncheon and afternoon), Herbert J. Scholz; *Secretary* H. H. Henline.

Scintillation Counter Symposium Planned for January 29 and 30

A Scintillation Counter Symposium will be held in the main auditorium, Bureau of Standards, Washington, D. C., on January 29 and 30. The symposium is being sponsored by the AIEE, the Institute of Radio Engineers (IRE), the Atomic Energy Commission, and the National Bureau of Standards. Attendance at the Symposium will be by invitation. Invitations and information can be obtained from the Chairman of the Publicity and Attendance Committee: R. W. Johnston, Radiation Instruments Branch, Atomic Energy Commission, Washington 25, D. C.

The Symposium will be divided into four sessions, each session having four papers of 1/2-hour duration. Those presenting papers are requested to submit an abstract of 300 to 500 words in length by January 2. The abstracts will be included with the program to be furnished to those attending the meetings. Following these papers, there will be a period of approximately 1 hour for discussion. Slides may be used in the discussion. In as far as it is possible, the discussion will be planned in advance. Those having material relating to the papers to be presented at the Symposium are requested to contact the Chairman of the Program Committee in advance of the meeting: G. A. Morton, RCA Laboratories, Princeton, N. J.

The local sections of AIEE and IRE are planning an evening meeting for January 29, and those attending the Symposium will be invited to attend. A topic of current interest in the nuclear field will be discussed at this meeting.

A block of rooms is being set aside at the Hotel Shoreham (at $9.00 per day for single occupancy). A registration fee for the Symposium will be $2.00.

TENTATIVE PROGRAM

Session I

Two New Photomultipliers for Scintillation Counting, RCA Laboratories

Some Observations on Pulse Height Resolution and Photosensitivity, *R. Swank*

Scintillation Counter Spectrometry, *P. R. Bell*

After-Pulsing in Photomultipliers, *D. W. Mueller*

Session II

High Energy Particles and the Scintillation Counter, *L. F. Wouters*

Crystal and Liquid Phosphors, *G. T. Reynolds*

Neutron Detecting Phosphors, *J. C. Schenck*

Temperature Effects in Phosphors, *S. H. Liebson*

Session III

Emission Time of Secondary Electrons, *R. R. Law*

High Speed Circuitry or Time Resolution in Scintillation Counters

6BN6 Fast Coincidence Circuit, *J. Marshall, J. Fischer*

Time Measurements with Coincidence Circuits, *S. De Benedetti*

Session IV

Performance of Pulsed Multiplier, *R. F. Post*

Highspeed Oscilloscope, *C. H. Smith*

Pulse Height Selector Problem, *G. G. Kelley*

An Analysis of New Electronics Required for Optimum Use of Scintillation Counters, *W. E. Higgenbotham*

Fortescue Fellowship Applicants Must File by February 15

Funds have been made available for one or more Charles LeGeyt Fortescue Fellowships for 1952–53. The awards are made to postgraduate students in the field of electrical engineering who have received their baccalaureate degree from a duly recognized technical school in the United States or Canada. The awards range from $1,000 to $1,500 per annum, depending upon the decisions of the committee in charge.

Candidates for the Charles LeGeyt Fortescue Fellowships should file applications on the form provided by AIEE so that they reach the Secretary of the Fellowship Committee by February 15, 1952. Awards will be made not later than April 1. Copies of the application forms are available at accredited colleges or at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

The Charles LeGeyt Fortescue Fellowship, sponsored by AIEE, was established in 1939 as a memorial to Charles Fortescue in recognition of his valuable contribution to the electric power industry. To this end the Westinghouse Electric Corporation, with which Doctor Fortescue was associated throughout his professional career, set up a trust fund of $25,000 to provide graduate fellowships in electrical engineering.

The successful candidates are selected by the AIEE committee which administers the fund.

It is intended that candidates shall pursue their studies at accredited engineering schools and engage in research problems meeting the approval of the Fellowship Committee. To be eligible, the student must have received a bachelor's degree from an accredited college by the time his work under the fellowship would begin, provided he does not hold or subsequently receive any other fellowship which carries a stipend greater than the tuition required by the institution at which the graduate work is to be undertaken.

Induction and Dielectric Heating Conference to Be Held in Feb.

A special technical conference on Induction and Dielectric Heating will be held on February 19 and 20, 1952, at the Carter Hotel in Cleveland, Ohio. It is being sponsored by the AIEE Subcommittee on Induction and Dielectric Heating, and the Cleveland Section will participate and assist in its execution.

There will be ten papers on induction and dielectric heating of interest to user and manufacturer alike. The papers will cover the following subjects: transmission lines for induction heating; the problem of radio interference from such equipment and its control; choice of frequencies for induction heating; dielectric heating in the rubber industry; 60-cycle induction heating; dielectric core baking; electrical codes and standards; and design of mechanisms for induction and dielectric heating.

It is planned to have a maximum of five sessions during the 2-day period. Four of these sessions will be devoted to papers and the last session will consist of a "Board of Experts" question and answer period.

Electronic Converter Conference to Be Held in Pittsburgh in May

The Committee on Electronic Power Converters and the Subcommittee on Electron Tubes of the Committee on Electronics are sponsoring a joint conference with the AIEE Pittsburgh Section on Electronic Converter Applications and Tubes. The conference will be held at the William Penn Hotel, Pittsburgh, Pa., on May 19 and 20, 1952. The date was originally announced as May 5 and 6.

This is the third of the series of conferences on electron tubes and will be devoted to problems of design, application, and operation of electronic power converters employing high power mercury-pool tubes and related devices.

Preliminary plans for the conference were outlined at a meeting of the Executive Committee held in Pittsburgh on October 25, 1951. C. C. Herskind and H. Winograd will serve as co-chairmen of the conference with W. A. Albert representing the Pittsburgh Section.

Continued Trial Use Advocated for Transformer Standards

At a meeting of the AIEE Transformer Committee in Cleveland, Ohio, on September 21, it was decided by majority vote to continue for trial use until January 1, 1953, the tentative standard of 110 degrees centigrade for the hottest-spot temperature rise for class-*B* insulation in dry-type transformers.

This change to the transformer standards was originally agreed to by the Transformer Committee in 1949 for trial use for one year subject to the results of a study being conducted on the aging characteristics of class-B insulating materials by a working group of the Transformer Committee (*EE, vol. 68, Nov. '49, pp 955–6*). However, since the tests on which this study was to be based have not progressed far enough to establish a more definite value now, it was agreed by a majority of the committee at the Cleveland meeting that the 110-degree-centigrade limit should continue to be used on a tentative basis. As in the case of the original recommendation, there is still considerable difference of opinion among the members of the committee concerning this limit, therefore the 110-degree value continues to represent a compromise figure. It is hoped that by the end of this second trial period sufficient data will be obtained from which to establish a standard value.

The following, taken from the 1949 report, is the tentative standard suggested for trial use until January 1, 1953: "Insert 110 degrees centigrade in the column of Table 11.021 giving hottest-spot temperature rise for class-B insulation and modify it by the following note: 'A value of 110 degrees centigrade was agreed upon by the Working Group of Subject 6 and was accepted by the Transformer Committee as a tentative limiting hot-spot temperature rise for dry-type transformers insulated with class-B insulation. There was considerable difference of opinion among the members of the working group and of the main committee as to what values should be used for the hottest-spot temperature rise. Values considerably higher and lower than 110 degrees centigrade were suggested based on the experience and judgment of different individuals. Some consider the value of 110 degrees centigrade extremely conservative; others consider it as being higher than is justified by the available data. Accordingly, this value represents a compromise figure to be used as a tentative value subject to the results of the study of the aging characteristics of class-B insulating materials which has been assigned to one of the other working groups of the Transformer Committee.' "

AIEE and AIA Presidents Honored at Dinner in Portland

The national presidents of the American Institute of Electrical Engineers and American Institute of Architects (AIA), F. O. McMillan of Corvallis, Oreg., and Glenn Stanton of Portland, Oreg., were honored by a dinner in Portland on November 15. The dinner meeting was sponsored by the Oregon Technical Council (OTC). John Correnbaum, president of the OTC, opened the meeting, and Jack Annand, AIA, acted as toastmaster. Walter W. R. May, publisher of Oregon City's Enterprise-Courier, was the main speaker.

Oregon State College's Head of the Electrical Engineering Department, F. O. McMillan, was recognized for his enthusiastic work on various technical and administrative committees of AIEE with the announcement in June of his election as president of that organization for the 1951–1952 year. Mr. McMillan is well known for his investigations and publications on electric apparatus, his teaching, public service as a state department consultant to the Chinese Government, and service to other technical societies.

Mr. Stanton is a fellow in the AIA and recently was elected to the presidency for the 1951–1952 year. He is a member of many technical societies and fraternal organizations and has taken active part in numerous civic functions.

St. Louis Meeting April 15–17. A broad and varied technical program is being planned for the South West District Meeting to be held in St. Louis, Mo., on April 15, 16, and 17, 1952. Student sessions are scheduled for April 18 and 19 so that those interested can participate in both meetings.

I. T. Monseth has been appointed General Chairman of the meeting. He is aided by R. C. Horn, *Vice-Chairman;* R. W. Schoetker, *Secretary-Treasurer;* H. R. Fritz, *District Vice-President;* R. G. Meyerand, *District Secretary;* and R. N. Slinger, *Chairman of the St. Louis Section.* Mr. Monseth already has his committees organized and functioning smoothly so that a well-planned meeting is assured.

1952 Pacific General Meeting Committee. AIEE President McMillan has appointed the following as members of the general committee to make plans for the Pacific General Meeting which is to be held in Phoenix, Ariz., August 19–22, 1952: J. E. Redmond, *General Chairman;* T. M. Morong, *Vice-Chairman;* Americo Lazzari, *Secretary;* M. M. Bridgwater, *Treasurer;* George Groh, *Technical Programs;* E. A. Thomas, *Registration;* Walter Willson, *Hotels;* M. M. Bridgwater, *Finance;* Carl Poppino, *Inspection Trips;* C. R. Smith, *Transportation;* John Kimball, *Entertainment;* J. C. Clark, *Students;* Max Llewellyn, *Sports;* Mrs. J. E. Redmond, *Ladies';* Ben Ferguson, *Publicity;* and William M. Doak, I. G. Jenkins, Jr., Fay Percy.

1952 Fall General Meeting Committee. The following members of the Institute have been appointed by President McMillan to be members of the general committee to make plans for the Fall General Meeting which is to be held in New Orleans, La., October 13–17, 1952: James M. Todd, *Chairman;* Charles P. Knost, B. P. Babin, and B. Z. Segall, *Vice-Chairmen;* E. I. Blanchard, *Secretary-Treasurer;* E. S. Lammers, Jr., *Vice-President, District 4;* and H. E. Pritchard, Jr., and J. Robert Rombach, Jr.

AIEE Mississippi Section Meets. The regular monthly meeting of the AIEE Mississippi Section was held October 25 at the Heidelberg Hotel, Jackson, Miss. S. J. Rosch, consulting cable engineer, Anaconda Wire and Cable Company, was the guest speaker and was presented by W. L. Harp, Section Chairman. Mr. Rosch outlined the broad advances made by industrial research in all types of manufacturing, and discussed synthetic rubber, synthetic resins, and plastics and their relations to everyday life as well as to the electrical industry.

Committee on Transfers Personnel. The personnel of the AIEE Committee on Transfers was omitted from the list of Institute Committees published in the September issue of *Electrical Engineering* as the members had not yet been appointed. Members of the committee now are:

Charles B. Carpenter, *Chairman;*	Pacific Telephone and Telegraph Company, 509 S. W. Oak Street, Portland, Oreg.
Charles Clos, *Secretary*	New York, N. Y.
W. C. Bloomquist	Schenectady, N. Y.
F. A. Cooper	St. Louis, Mo.
C. W. Fick	Cleveland, Ohio
J. D. Harper	Alcoa, Tenn.
F. S. Himebrook	Dayton, Ohio
M. R. Horne	Dearborn, Mich.
L. F. Hunt	Los Angeles, Calif.
C. W. Keller	Denver, Colo.
John Wm. Robinson	San Francisco, Calif.
E. W. Stone	DeKalb, Ill.
J. J. Tesar	Cleveland, Ohio
W. W. Walters	Chicago, Ill.
F. W. Willcutt	Washington, D. C.
H. B. Wood	Boston, Mass.

COMMITTEE ACTIVITIES

Editor's Note: This department has been created for the convenience of the various AIEE technical committees and will include brief news reports of committee activities. Items for this department, which should be as short as possible, should be forwarded to R. S. Gardner at AIEE Headquarters, 33 West 39th Street, New York 18, N. Y.

General Applications Division

Committee on Air Transportation (D. E. Fritz, *Chairman;* W. L. Berry, *Vice-Chairman;* R. H. Keith, *Secretary*). A meeting of the committee was held on October 11, when it was decided to participate in the South West District Meeting. The committee has a large backlog of papers that have been approved for presentation, and it is anticipated that two sessions will be held at the meeting.

The committee also decided to hold its main session for 1952 in conjunction with the 1952 Middle Eastern District Meeting. It is hoped that at least four, and possibly six, sessions can be held at this meeting.

Among the new assignments given to the subcommittees was the program of standardization of performance curves for aircraft generators, in order that the users would be able to make direct comparisons between different makes of generators. This program was assigned to the Rotating Machinery Subcommittee.

Committee on Domestic and Commercial Applications (T. H. Cline, *Chairman;* T. C. Johnson, *Vice-Chairman;* J. P. Harris, *Secretary*). This committee has participated actively in the National Farm Electrification Conference with W. R. Crawford as Chairman of the Subcommittee on Farm Electrification.

The main committee also joined with the Committee on Rotating Machinery in sponsoring a 2-day Special Technical Conference on Motor Applications on Pumps and Refrigeration, with the Dayton Section acting as host. Also Mr. Cline and Dr. Hamburger represented the committee at the Safety Symposium held at the Fall General Meeting in Cleveland.

The committee is promoting another session on Electric Space Heating and Heat Pumps. This program is being arranged by Mr. Hoebel, Chairman of the Subcommittee on Space Heating and Heat Pumps for the East Coast and Mr. T. C. Johnson, Vice-Chairman of the main committee.

Another Technical Conference on Domestic Appliances will be held in the midwest in May of 1952, to be sponsored by the Subcommittee on Domestic Appliances under the Chairmanship of T. T. Woodson. The committee is attempting to arrange for the Cincinnati Section to act as host in this case.

Industry Division

Committee on Industrial Power Systems (H. G. Barnett, *Chairman;* S. A. Warner, *Vice-Chairman;* R. H. Whaley, *Secretary*). The Executive Subcommittee held its first meeting of this year during the Fall General Meeting to deal with current problems. One of the problems is getting started on technical session work sufficiently early to meet deadline dates.

Two technical sessions have been organized for the Winter General Meeting in 1952. One of these sessions will be a joint meeting with the Relay Committee with papers on the general subject of protective relaying in industrial plants involving the utility source of supply.

The Relay Committee and this committee are co-operating in establishing a Joint Working Group on Protective Relaying. This group is planning a chapter in the revision of the AIEE Special Publication Red Book entitled "Electric Power Distribution for Industrial Plants."

Committee on Industry Control (J. A. Cortelli, *Chairman;* H. L. Palmer, *Vice-Chairman;* L. H. Matthias, *Secretary*). The committee is planning a session at the Winter General Meeting on the general subject of the day-to-day problems encountered by the control engineer in the application of regulating systems in the field of industrial control.

Power Division

Committee on Power Generation (J. A. Brooks, *Chairman;* J. B. McClure, *Vice-Chairman;* H. R. Harris, *Secretary*). The committee is planning one session at the 1952 Summer General Meeting to be devoted to a round-table discussion of current power generation problems. As the session is being arranged by the Hydroelectric Systems Subcommittee, a large part of the discussion will center around hydroelectric problems. Questions will be proposed in advance and given some advance circulation so that studied answers may be given at the meeting. Any questions pertaining to power generation may be asked. Whether or not members are planning to attend the 1952 Summer General Meeting, any questions of general interest to electrical engineers in the power generation field should be sent to the Committee on Power Generation, AIEE, 33 West 39th Street, New York 18, N. Y.

Committee on Protective Devices (H. R. Stewart, *Chairman;* A. A. Johnson, *Vice-Chairman;* E. H. Yonkers, *Secretary*). This committee, including its subcommittees and working groups, comprises at present some 65 different individuals. It has a number of active projects in varying stages of completion. Among these is an Application Guide for the Lightning Protection of Substations which has involved a comprehensive study of lightning-arrester performance characteristics, steepness of wavefront and crest value of discharge current wave which will rarely be exceeded in service, and effect of distance between lightning arrester and protected equipment. When completed, this should be a very valuable reference for lightning protection and insulation co-ordination engineers. The several application guides on neutral grounding of various types of systems issued in the past three years by the committee have found wide use in the industry, and it is planned to have them submitted to the AIEE Standards Committee during the current administrative year for approval as standards. AIEE Standard *28-A* on Lightning Arresters, which has been in trial use for the past two years, is now in process of further revision to include developments which have occurred in that period.

A new working group is being set up to study the need for surge protection of neutral grounding devices.

Joint Subcommittee on the Application of Probability Methods to Power System Problems (Giuseppe Calabrese, *Chairman*). In 1950 this subcommittee initiated a survey of outage data of high-pressure boilers and turbines. The survey includes boilers with continuous rating of 200,000 pounds per hour or more of steam, at a pressure of 700 pounds per square inch gauge or higher, and turbines operating at 700 pounds per square inch gauge or more, having a capacity of 20 megawatts condensing, 10 megawatts superposed. The data are being collected under the auspices of the Edison Electric Institute. Replies have been received from about 70 companies. Results of the survey are not yet available but it is hoped that they can be made available in the very near future in a subcommittee report. The collection of data will continue until sufficient information is secured.

Science and Electronics Division

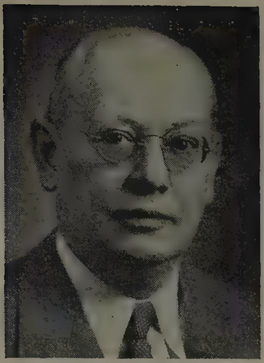
AIEE Joint Subcommittee on Telemetering (W. J. Mayo-Wells, *Chairman;* E. E. Lynch, *Secretary*). The Institute of Radio Engineers (IRE) has accepted the invitation of the AIEE to act as a joint sponsor of the proposed technical telemetering conference to be held on the West Coast in May 1952. Arrangements for this conference are well under way although the exact date and location have not yet been settled. Progress also has been made on securing papers and a program committee has been appointed.

The Subcommittee on Telemetering Terminology has secured support from both the AIEE Instruments and Measurements Committee and the IRE Measurements and Instrumentation Committee in favor of a joint AIEE-IRE committee for this purpose and hopes the necessary steps will be taken to bring this about as early as possible. One meeting of this subcommittee's working group has been held to lay the groundwork for increased activity in terminology and the services of Dr. W. A. Wildhack of the Bureau of Standards and Mr. R. L. McKay of the Corps of Engineers have been secured. The subcommittee has also contacted the American Standards Association and has requested from Mr. McNair a number of standards which apply to the telemetering field. It is hoped to hold another meeting of this working group in the very near future.

Joint Subcommittee on Electronic Instruments (Rudolf Feldt, *Chairman;* W. H. Tidd, *Vice-Chairman;* P. K. McElroy, *Secretary*). During the current year, the subcommittee has concentrated its work largely on establishing tentative performance specifications for electronic instruments. Three task groups have been set up for this purpose, working on cathode-ray instruments, vacuum-tube voltmeters, and signal sources respectively. This work is nearing completion with the final draft of specifications for signal sources recently reviewed by the committee. The only major job to be done is work on definitions for cathode-ray instruments. This work is making fine progress, but will still require some time before being completed.

AIEE PERSONALITIES . . . . .

C. F. Wagner (A '20, M '27, F '40), consulting engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., has been awarded the 1951 Edison Medal for "distinguished contributions in the field of power system engineering." The medal will be presented to Dr. Wagner at the AIEE Winter General Meeting. He was born on March 20, 1895, in Pittsburgh, Pa., and received a bachelor of science degree in electrical engineering from Carnegie Institute of Technology in 1917. He joined the Westinghouse Electric Corporation the year following his graduation and has been associated continuously with that company. From 1918–1923 he worked on a variety of problems in research and apparatus development. The next ten years were spent on the staff of the late C. L. Fortescue studying transmission system stability, short-circuit transients, machine performance under short-circuit conditions, and related fields. Dr. Wagner also worked on the research and development of mercury-arc rectifiers and inverter systems. Since 1938 he has held the position of consulting engineer and has had charge of Westinghouse research on lightning phenomena. Dr. Wagner is the



C. F. Wagner

author of many technical papers and the coauthor of several books. Twenty-five patents have been issued to him for inventions involving new and improved apparatus and systems of benefit to the electrical industry. He was awarded the honorary degree of doctor of engineering by the Illinois Institute of Technology in 1944. He is a member of the Franklin Institute, the American Association for the Advancement of Science, Tau Beta Pi, and Sigma Xi. Dr. Wagner is an active member of the Institute, having served on the following AIEE committees: Transmission and Distribution (1930–32, 1937–52, Chairman 1947–49); Publicity (1945–47); Planning and Co-ordination (1945–47); Award of Institute Prizes (1945–47); Publication (1943–49, Chairman 1946–47); Standards (1947–49); and Technical Program (1947–49).

E. B. Noel (A '45), development engineer, Lamp Development Laboratory, General Electric Company, Cleveland, Ohio, has been awarded the Photographic Society of America's technical journal award for "the most significant contribution in the technical or scientific fields" for 1951. The award was given for a paper entitled "A New Low-Voltage Low-Power Flashtube of High Efficiency." The award-winning paper deals with the design and characteristics of a new flashtube for use with lightweight mobile power units.

N. M. DuChemin (A '29, M '47), general manager, small apparatus division, General Electric Company, New York, N. Y., has been elected a Vice-President of the company. He began his career with General Electric in 1914 and held successively the positions of works manager at Lynn, Mass., manager, meter and instruments divisions, assistant general manager of the Apparatus Department, and general manager of the small apparatus division. He is a member of The American Society of Mechanical Engineers.

W. L. Roberts (M '48), electronics engineer, Research Laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa., has won the annual cash award from the American Welding Society for the best paper on resistance welding. The paper was entitled "Resistance Variations During Spot Welding." Before joining Westinghouse Mr. Roberts was associated with the Federal Telecommunications Laboratories. He joined Westinghouse in 1948 as a member of the Electronics and Nuclear Physics Department, and shortly afterward was assigned to the welding section to handle electronic problems there.

Frank Wenner (A '12, F '26, Member for Life), consulting physicist, Rubicon Company, Philadelphia, Pa., has been appointed to the consulting staff of the National Bureau of Standards, Washington, D. C. Dr. Wenner was an employee of the National Bureau of Standards (NBS) from 1907 to 1943, at which time he was chief of the resistance measurements section in the NBS electricity division. From 1947–48 he was connected with The Johns Hopkins University where he helped develop military equipment. Dr. Wenner is a member of the American Physical Society and the American Geophysical Union. He was a member AIEE Standards Committee (1923–28).

D. B. Sinclair (M '45, F '51), chief engineer, General Radio Company, Cambridge, Mass., has been elected President of the Institute of Radio Engineers for 1952. A graduate of Massachusetts Institute of Technology, he also received his master of science and doctor of philosophy degree there. Dr. Sinclair became associated with the General Radio Company in 1936, was named assistant chief engineer in 1944, and six years later was appointed chief engineer of the company. He worked in the guided missile division of the National Defense Research Committee during World War II, receiving the President's Certificate of Merit for outstanding services. He served on the AIEE Instruments and Measurements Committee (1948–50).

F. C. Todd (A '27, M '49), assistant supervisor, industrial physics division, Battelle Memorial Institute, Columbus, Ohio, has been named supervisor of a newly formed division of electronic physics. A member of the Battelle staff since 1942, Dr. Todd has been associated with much of the recent work on electronic mechanisms. He is a member of the American Physical Society, the American Institute of Mining and Metallurgical Engineers, the American Association for the Advancement of Science, and Sigma Xi. He served on the AIEE Electronics Committee (1947–48).

Alvah Small (M '37, F '43), retired, New York, N. Y., has been cited by the American Standards Association for "his outstanding contributions to the art of fire prevention through the application of the principles of standardization to the work of development and revision of the National Electric Code and its recognition and utilization as the guide to the safe installation and use of electrical wiring and apparatus. . . . ." Mr. Small recently retired as Vice-Chairman, Underwriters' Laboratories, Inc., after 45 years' service with the company. Mr. Small served on the AIEE Safety Committee (1937–39).

Zay Jeffries (M '36, F '42), retired, Pittsfield, Mass., has been made an honorary member of the Japanese Institute of Metals. He is the first non-Japanese ever to be so honored. Dr. Jeffries retired in 1949 as Vice-President of the Chemical Department of the General Electric Company. He had been associated with General Electric since 1914. Dr. Jeffries served the AIEE on the Edison Medal Committee (1945–50).

R. C. Bergvall (A '24, F '50), engineering manager, industrial products division, Westinghouse Electric Corporation, Pittsburgh, Pa., has been appointed manager of engineering, defense products. Mr. Bergvall joined Westinghouse in 1921 after his graduation from the University of Michigan. He is an active member of the Institute, having served on the following committees: Protective Devices (1932–33); Standards (1943–52); Nucleonics (1946–49).

Irven Travis (M '46), Director of Research, Burroughs Adding Machine Company, Philadelphia, Pa., has been cited for outstanding accomplishments in the field of electronic computers by Drexel Institute. He is a member of the Institute of Radio Engineers, Sigma Xi, Tau Beta Pi, and Eta Kappa Nu. Dr. Travis served the Institute on the Electronics Committee (1950–51).

Herbert Hoover (HM '29), Palo Alto, Calif., has been awarded the Howard Coonley Medal by the American Standards Association for "his work in national standardization projects when he was Secretary of Commerce in the 1920's and for the importance he placed on administrative standards in the Hoover Commission Report for government reorganization issued in 1949."

B. D. Loughlin (A '40), supervising engineer, Research Department, Hazeltine Electronics Corporation, Little Neck, N. Y., has been awarded the Vladimir K. Zworykin Television Prize Award for 1952 by the Institute of Radio Engineers for his outstanding technical contributions to television. This is the first time that this award has been conferred.

J. D. Ryder (A '40, M '46), professor and Head, Electrical Engineering Department, University of Illinois, Urbana, Ill., and **Ernst Weber** (A '31, F '34), Head, Electrical Engineering Department, Polytechnic Institute of Brooklyn (N. Y.), have been elected as Directors of the Institute of Radio Engineers for the 1952–54 term.

J. L. McKeever (A '32, M '47), division engineer, industrial and central station engineering division, Canadian General Electric Company, Ltd., Peterboro, Ontario, Canada, has been appointed works engineer of the Peterboro Works. He is a member of the Canadian Electrical Association and is currently serving the AIEE on the Industrial Power Systems Committee.

E. D. Talbot (A '09, F '36, Member for Life), consulting telephone engineer, Rochester, N. Y., has joined the staff of The J. G. White Engineering Corporation of New York, in their Djarkarta, Indonesia, Department. He will serve as communication consultant to the Government's Telegraph and Telephone Department.

L. E. Legg (M '49), supervisor of automatic train control, Chicago and Northwestern Railway, Chicago, Ill., has been appointed electrical engineer in charge of design, installation, and maintenance of electric and train control equipment on motive power and cars. Mr. Legg has been with the Chicago Northwestern Railway since 1928.

T. W. Metz (A '47), sales representative, Allis-Chalmers Manufacturing Company, Dallas, Tex., has been appointed manager of the Indianapolis district of the company's general machinery division. Mr. Metz has been with Allis-Chalmers since 1939.

M. S. Shane (A '30, M '36), supervisor, Technical Studies Department, Cleveland Electric Illuminating Company, Cleveland, Ohio, has been elected a Director-at-Large of the American Welding Society. He is currently serving the AIEE on the Electric Welding Committee.

J. H. Behm (A '50), assistant manager, fractional-horsepower motor engineering division, General Electric Company, Fort Wayne, Ind., has been appointed staff assistant to the manager of engineering of General Electric's small apparatus division at Lynn, Mass. Mr. Behm has been with the company since 1931.

Harrison Johnston, IV (A '48), engineer, Apparatus Department, General Electric Company, San Francisco, Calif., has been appointed manager of the product engineering division of the Ampex Electric Corporation, Redwood City, Calif. Mr. Johnston had been associated with General Electric for 12 years. He is a member of the Institute of Radio Engineers.

A. L. Matte (A '10, M '36, Member for Life), retired, New York, N. Y., has accepted a position as assistant professor of electrical engineering at Polytechnic Institute of Brooklyn (N. Y.). Mr. Matte retired recently from the Bell Telephone Laboratories after 33 years' service with the company. He is a member of the American Physical Society.

P. S. Gregory (M '43), Vice-President, Power Sales Department, Shawinigan Water and Power Company, Montreal, Quebec, Canada, has been elected a Director of the company. Mr. Gregory joined the company in 1918 and became assistant general manager in 1930 and Vice-President in 1941.

J. H. Goss (A '35, M '43), manager of engineering, control divisions, General Electric Company, Schenectady, N. Y., has been appointed manager of manufacturing of the appliance division. Mr. Goss has been associated with the General Electric Company since 1931.

Michael Pope (A '47), consulting engineer, Myers and Addington, New York, N. Y., has been admitted as a junior partner in the firm.

OBITUARY

Roy Martin Smith (A '35, M '46), chief engineer, Railway and Industrial Engineering Company, Greensburg, Pa., died on October 30, 1951. He was born on March 24, 1903, in Spokane, Wash., and was graduated from the University of Wisconsin in 1925 with a bachelor of science degree in electrical engineering. He was associated with the Westinghouse Electric Corporation from 1925 to 1941 where he was in charge of design and application of protective relays. In 1941 he became engineering manager of the Bryant Electric Company and a year later accepted the position of chief engineer of the Roller Smith Company. He joined the Railway and Industrial Engineering Company in 1945 as distribution engineer and was appointed chief engineer in 1950. He was an active member of the Institute, having served on the Protective Devices Committee (1936–45) and the Instruments and Measurements Committee (1942–44).

Walter Pearce Holcombe (A '06, M '13, Member for Life), retired, Babson Park, Fla., died on September 19, 1951. He was born in Mobile, Ala., on November 20, 1875, and was graduated from Centenary College in 1896 with a bachelor of science degree. He began his career with the Electric Light Company of Mobile and worked subsequently in St. Louis, Mo., and Detroit, Mich., before joining the Brooklyn Edison Company, now a part of the Consolidated Edison Company of New York, Inc. He joined the company in 1920 as a purchasing agent and in 1926 was made Vice-President in charge of purchasing and transportation. He was elected Vice-President and assistant to the vice-chairman of the board 12 years later, posts which he retained until his retirement in 1941.

James Webster Watson (A '08, Member for Life), Chairman, Department of Electrical Engineering, University of Wisconsin, Wis., died on October 4, 1951. He was born on January 16, 1879, in La Crosse, Wis., and was graduated in 1902 from the University of Wisconsin with a bachelor of science degree in electrical engineering. He joined the faculty of the University after his graduation and was associated with it continuously until his retirement in 1949. He was a member of the American Society for Engineering Education, Tau Beta Pi, Sigma Xi, and Eta Kappa Nu.

William B. Creagmile (A '07, Member for Life), retired, Norwood, Pa., died on September 12, 1951. He was born in Philadelphia, Pa., on August 13, 1875, and was graduated from the School of Engineering, Drexel Institute, in 1896. Mr. Creagmile was retired from the James G. Biddle Company, Philadelphia, Pa.

Homer C. Paiste (A '24), superintendent of substations, Ohio Edison Company, Akron, Ohio, died on October 26, 1951. He was born on July 15, 1887, in Chester, Pa., and attended Drexel Institute. He had been associated with the company since 1917.

MEMBERSHIP

Recommended for Transfer

The Board of Examiners at its meeting of November 15, 1951, recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute. A statement of valid reasons for such objections, signed by a member, must be furnished and will be treated as confidential.

To Grade of Fellow

Bartholomew, F. J., pres., Electric Power Equipment, Ltd., Vancouver, B. C., Canada
Clare, C. P., pres., C. P. Clare & Co., Chicago, Ill.
Oetinger, H. W., exec. assistant, Duke Power Co., Charlotte, N. C.

3 to grade of Fellow

To Grade of Member

Ambrogi, J. N., Jr., electronics engr., U. S. Naval Air Development Center, Johnsville, Pa.
Bellingham, L. C., elec. engr., The National Varnished Products Corp., Rahway, N. J.
Bracken, J. F., senior engr., Commonwealth Edison Co., Chicago, Ill.
Burnett, J. H., asst. secy. & sales mgr., Electrons, Inc., Newark, N. J.
Caruthers, J. E., elec. engr., Arkansas Power & Light Co., Pine Bluff, Ark.
Cheadle, J. N., assoc. prof. of elec. engg., South Dakota State College, Brookings, S. D.
Cox, J. L., vice pres., Duro-Test Corp., North Bergen, N. J.
Demaree, D. M., elec. consulting engr., 419 Arizona Title Bldg., Phoenix, Ariz.
Dukes, R. C., vice pres. & genl. mgr., Dukes & Dukes, Inc., Orangeburg, S. C.
Duncan, C. S., research engr., Westinghouse Research Laboratories, East Pittsburgh, Pa.
Duncan, T. C., distribution engr., Consolidated Edison Co. of N. Y., Inc., New York, N. Y.
Gockley, R., engr., Southern California Edison Co., Los Angeles, Calif.
Hanson, F. L., mgr., publicity div., The Ideal Electric & Mfg. Co., Mansfield, Ohio
Jacobs, M. C., vice pres., All States Electric Co., Inc., Jamaica, N. Y.
Ketchum, P. M., elec. engr., General Electric Co., Syracuse, N. Y.
McCloskey, W. J., elec. design engr., Westinghouse Electric Corp., East Pittsburgh, Pa.
McCrea, W. S., consulting engr., 241 Perkins Bldg., Tacoma, Wash.
Myers, J. L., utilities engr., Libbey-Owen-Ford Glass Co., Toledo, Ohio
Olsen, E. H., div. engr., Pacific Power & Light Co., Walla Walla, Wash.
Shackelford, L. C., wire & cable specialist, General Electric Co., Seattle, Wash.
Shafler, D. B., div. engr., Monongahela Power Co., Parkersburg, W. Va.
Sinderson, L. O., sales engr., General Electric Co., Chicago, Ill.
Straussman, A. D., elec. engr., Ebasco Services, Inc., New York, N. Y.
Sutton, H. J., engg. specialist, Gulf States Utilities, Beaumont, Tex.
Taylor, L. M., plant & equipment engr., Thomas A. Edison Inc., Bloomfield, N. J.

25 to grade of Member

Applications for Election

Applications for admission or re-election to Institute membership, in the grades of Fellow and Member, have been received from the following candidates, and any member objecting to election should supply a signed statement to the Secretary before January 25, 1952, or March 25, 1952, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Member

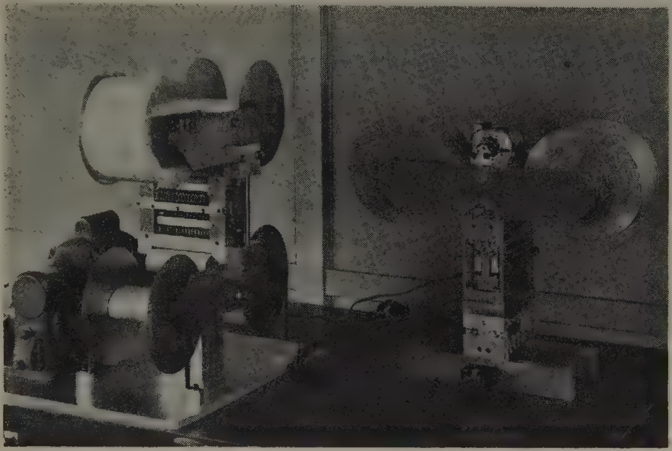
Breitenbach, H. W., E. E. Co., England, with English Electric Co. of Canada, Ltd., St. Catharines, Ont., Canada
Engel, G. W. (re-election), R. D. 1, Charlton, Ballston Lake, N. Y.

2 to grade of Member

OF CURRENT INTEREST

Skillful Robot Does Complex Machining from Perforated Tape Blueprints

A robot machinist has been developed which will operate a machine tool from an engineer's office or other distant points, it was announced recently by Daco Machine and Tool Company, Brooklyn, N. Y. According to Daco engineers remote control possibilities are practically unlimited; it would be just as easy to have a robot located in Detroit, for example, operate, via teletype, machine tools which were located in Los Angeles or New Haven.



Heart of the Daco-developed automatic machinist is a punching mechanism which translates blueprint co-ordinates into tape perforations (left). The sensor (right) converts these perforations into electric signals

Ideal for mass production plants having long repetitive runs of metal-cutting operations, the robot has wide application in all types of defense production. Complicated machining operations would no longer depend on the skill of the operator; the skill lies in the electric robot.

The parts that make up the Daco-built device are a paper-tape perforator, a sensor that translates the tape message into electric impulses that actuate selsyn motors which, like the operator's hands, tell the machine what to do. Perforations in the tape represent essential dimensions shown on the blueprint for the part to be machined. When the tape travels through the sensor, electric contacts are made and broken through the holes to complete and break electric circuits. This produces varying voltages in the sensor that accurately control movement of the cutting tool and work piece in the machine.

Unlike similar electronic brains, machining accuracy is in no way influenced by the robot. Deviations in the dimensions of the machined part, if any, are the fault of the tool.

About the only manpower needed around the machine tool is for loading and unloading the work. As is usually done, dimensions will be checked periodically to see that parts are within tolerance limits and to determine when worn tools need to be replaced.

The robot is flexible, too, because it is not wedded to the machine tool. Once a production run is completed on a given machine, the brain can be attached to another and set up to do a completely different job.

The brains of the device are in the tape. It can be punched out by a draftsman who makes computations from a blueprint. In effect, he places the part drawing over a grid-like graph paper. Holes in the tape represent points and surfaces on the part. A plant operating such robots would probably keep a file of master tapes representing various arcs, flat surfaces, and fillets. To set up a tape for machining a part, a series of master tapes of the right combination could be fastened together.

Future Meetings of Other Societies

Hydraulic Institute. January 30–February 1, 1952, Seaview Country Club, Absecon, N. J.

Institute of Aeronautical Sciences. 20th Annual Meeting. January 28–February 1, 1952, Astor Hotel, New York, N. Y.

Institute of Radio Engineers. Annual Convention. March 3–6, 1952, Waldorf-Astoria Hotel and Grand Central Palace, New York, N. Y.

Instrument Society of America. Power Plant Symposium held by New York Section. February 7–8, 1952, Hotel Statler, New York, N. Y.

Pennsylvania Electric Association. Prime Movers and Electrical Equipment Committees. February 28–29, 1952, Benjamin Franklin Hotel, Philadelphia, Pa.

Plant Maintenance Conference. Third Annual Meeting. January 14–17, 1952, Convention Hall, Philadelphia, Pa.

Society of Plastics Engineers, Inc. Eighth Annual National Technical Conference. January 16–18, 1952, Edgewater Beach Hotel, Chicago, Ill.

United States Navy to Use Underwater Television to Safeguard Human Divers

Underwater television may be used by the United States Navy to protect as well as aid human divers in their work, it was disclosed recently. Television cameras can explore undersea areas to help divers spot and prepare for dangerous situations. In addition, the cameras may be used to observe the work of divers, making possible shipboard co-ordination of underwater activities.

The process which is expected to reduce the number of dangers which divers must face was developed over a period of 3 years.

Perhaps the first use of underwater television was during the evaluation of the Bikini atom bomb tests in 1947. The camera was lowered from a control ship to depths as great as 180 feet, and was manipulated and focused by remote control from above. In some cases it photographed objects 30 feet away, transmitting images clearly and accurately. During one experiment, two cameras were used simultaneously.

The new underwater television cameras developed under the direction of the Bureau of Ships enable viewers to see conditions where diver operation is not possible. A broad view of the whole area in which work is being done is provided by a wide-angle lens on the camera. When desired, a close-up of specific details can be provided simply by closing a switch on shipboard. This changes the camera lens from wide angle to telephoto.

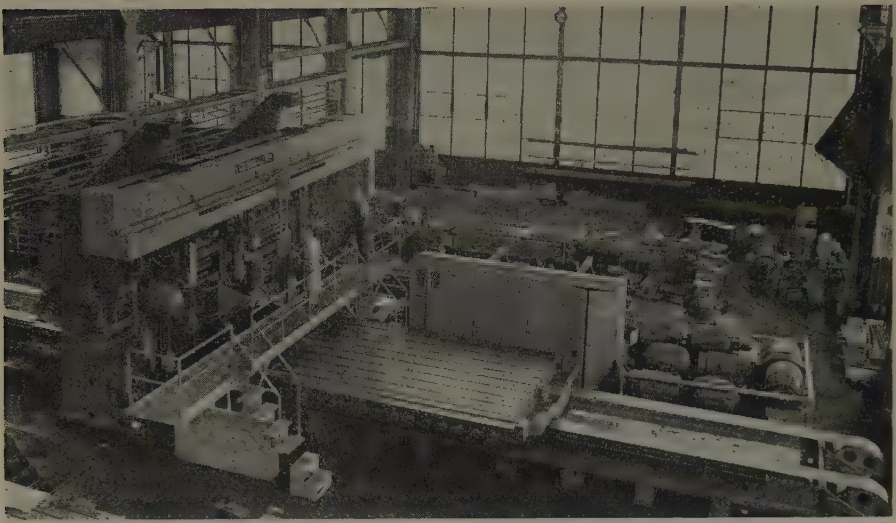
It is hoped that one of the chief advantages of this system will be the time saved in underwater exploration. The time a diver can spend under water is limited severely due to the water pressure and to the time it takes to lower and raise him. Indeed, at depths of more than 200 feet, the time spent lowering and raising a diver exceeds the time a diver can spend on the bottom.

Television cameras, however, may be lowered quickly to the area. Used sometimes with suspended lights, they may enable personnel on the ship to examine accurately the ocean bottom for long periods of time. The pictures appearing on the television screen also can be filmed if further reference to them is necessary.

Also, individuals walking on the ocean floor may raise clouds of silt, which obstruct their vision. This is avoided by the use of the television cameras, which need not touch bottom, and thus may provide better visibility both as to distance and clarity than human divers have.

Another problem which the use of underwater television may help to meet is that of

Three-Dimensional Milling Machine Speeds Defense Effort



A 3-dimensional milling machine capable of machining integral rib-skin panels from solid or rough forged aluminum alloy plates has been developed to help speed the defense effort by the Giddings and Lewis Machine Tool Company in co-operation with the General Electric Company. This manufacture of airplane surfaces and their stiffening elements as a unit will permit use of the thinner wings and sharper fuselages required for high-speed jet flying. The machine tool operates in three dimensions with two feed motions. A 2-dimension electronic tracer control is used to guide the longitudinal and lateral cutting motions simultaneously. The machine is 18 feet high, 30 feet wide, 80 feet long, and weighs 200 tons

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observing changing bottom conditions in areas where this happens rapidly. In this way chart corrections are facilitated. Underwater conditions frequently depend upon surface conditions, especially in navigable shallow waters. If a storm arises, the ocean bottom may change shape. In deep water, if divers are below during rough water, their lives are endangered. If not, their work is made more difficult and time is lost in resurveying.

Observers on the surface may plan a salvage operation prior to sending divers down by using underwater television. Diving time then would be reduced to that necessary for the diver's actual work.

New Electronic Device Used to De-Ice TV Tower Transmitters

An electronic glove designed to keep ice off television transmitting towers and to give better winter reception is being installed on the 1/4-mile-high television (TV) mast above the 102-story Empire State Building. A fraction of an inch of ice coating on any one of several critical points is sufficient to put TV programs off the air. To overcome this weather hazard, a special heating system will be installed on each of the units from which five New York stations are transmitting, and possibly more will transmit in the future.

The electronic system was designed by Minneapolis-Honeywell Regulator Company to react to temperatures at the mast level. When temperatures near the freezing point, two Honeywell thermostats, similar to those used in homes, will send a signal to an electronic control device. Day and night, this instrument will automatically send heat-producing power, when needed, to each transmitting element, keeping them warm enough to prevent icing.

Icing conditions are not confined to the winter months. Workmen who pushed the TV pinnacle of steel upward frequently ran into icing conditions even when mild weather prevailed at street level 1,472 feet below. It is estimated that temperatures at mast and street level vary as much as 15 degrees.

Oddly enough, the worst ice formations can occur during fair weather, say TV engineers, who explain that under such conditions moist air rising from street level tends to condense on the cold metal of the mast. If mast-height temperatures are near freezing at such times the condensation will change to ice and possibly black out programs being transmitted.

Dust is another enemy of good reception that is controlled by the electronic gloves. Engineers explain that because of the presence of large bodies of water around New York, moist air tends to condense on the tower and attract and hold dust particles. Controlled heating of the elements reduces this condensation.

New Jersey Superhighway Installs Microwave System

One of the most modern highway communication control systems in the nation is being installed by the New Jersey Turnpike Administration on the new toll superhighway stretching from the Delaware River Bridge at Pennsville, N. J., to the New York State border. The system provides a flexible and dependable means for channeling traffic control, accident handling, and road maintenance calls; it was developed through the joint efforts of the Paul Godley Company and the Radio Corporation of America.

The microwave system, operating at a frequency of 960 megacycles, provides a voice channel for monitoring the entire system, another for dial-phone administrative calls, two voice channels for communication with state police cars and maintenance trucks fitted with 2-way mobile radio equipment, and one party-line teletype. At five of the system's seven 150-foot microwave towers there are very-high-frequency base stations which maintain contact with police cars and maintenance trucks, furnishing 2-way mobile radio coverage for the length of the new turnpike.

The new radio installation obviates the need for underground cables or overhead pole-and-wire lines as a means of communication, and assures continuous functioning through sleet, snow, and windstorm. The new facilities provide the Turnpike Administration at New Brunswick, N. J., with a means of instantaneous communication with all state troopers, maintenance trucks, and toll gates along the road. The dial phones and teletype link the police divisions along the turnpike with one another and with the State Police Headquarters at Trenton, N. J.

Unique very-high-frequency directional antennas also have been developed which assure a strong signal along the highway with a minimum possibility of interference to and from adjacent communities. They also enable mobile units to select between two base stations in areas where their signals overlap and would otherwise confuse reception. A switching arrangement at the turnpike headquarters permits separation of the system into two, three, or four sections, increasing both the flexibility and the message capacity of the system. When tied end-to-end, the system is essentially one large party line. If serious traffic congestion develops in any one region, the New Brunswick headquarters can isolate that section of the communication system, leaving it free to handle its local affairs without tying up calls for the rest of the turnpike. However, headquarters is still in a position to monitor messages exchanged in the area, and, by a throw of a switch, can bring it back into the over-all system when it seems advisable.

National Science Foundation to Award Graduate Fellowships

Approximately 400 graduate fellowships will be awarded by the National Science Foundation (NSF) for the academic year 1952–53 in the mathematical, physical, medical, biological, and engineering sciences. Fellows may elect to receive training in fields which combine two or more of these sciences. No awards will be made for study in clinical medicine, although applications will be considered from medical students who wish to prepare for careers in medical research.

The majority of National Science Foundation fellowships will be given to predoctoral applicants, particularly to those who will be eligible to begin graduate study during the coming year. Predoctoral fellows will be selected on the basis of ability, determined by means of scores made on tests of scientific aptitude and achievement, academic records, and recommendations regarding each candidate's abilities. The testing and evaluation of applicants will be carried on by the National Research Council. Final selection will be made by the National Science Board of the National Science Foundation. A limited number of postdoctoral fellowships will also be awarded.

Fellows may pursue their training at accredited nonprofit institutions of higher education in the United States or similar institutions abroad approved by the Foundation. A fellow must show that he will be accepted by the institution in which he plans to study before his fellowship award is confirmed finally.

Stipends for NSF Fellowships will vary with the academic status of the recipients. First-year fellows, those who expect to enter upon graduate study for the first time after June 1952 or those who have less than one year of graduate study, will receive a stipend of $1,400. Second-year fellows will receive $1,600, and advanced predoctoral fellows $1,700. The basic stipend for postdoctoral fellows will be $3,000 per year. Second-year, advanced predoctoral, and postdoctoral fellows will receive additional allowances for wives and children. Normal tuition and laboratory fees will be paid by the Foundation, and limited allowances to aid in defraying costs of travel will be provided.

National Science Foundation fellows will be expected to devote full time to advanced scientific study or scientific research for the tenure of the fellowship. Fellows may not receive remuneration from other fellowships or similar awards nor from Federal grants or contracts during the tenure of the fellowship.

The results of research carried out by a fellow during his training will be made available to the public without restriction, except as is required in the interest of national security.

Application forms for National Science Foundation graduate fellowships are available from the Fellowship Office, National Research Council, Washington 25, D. C. In order to be considered for the 1952–53 academic year, completed applications must be returned to the Fellowship Office, National Research Council, by January 7, 1952. The affidavit and loyalty oath required by the National Science Foundation Act of 1950 will constitute part of the application form and must be completed and returned with other application materials.

New Antenna Research Laboratory to be Built

A new antenna laboratory will be erected by the Workshop Associates, division of The Gabriel Company, Cleveland, Ohio, it was announced recently. To be located in Natick, Mass., the laboratory is scheduled for completion in mid-1952.

The laboratory site consists of a 46-acre tract approximately 20 miles from Boston. The building will be two stories with a modern glass brick front. The roof will be designed especially for outdoor antenna work. Electrical engineering, mechanical engineering, model shop, and a drafting department will all be located in the laboratory, together with all engineering offices for the Workshop Associates.

As the first industrial laboratory to be designed primarily for antenna research, the building will have many unique refinements. In addition to the special roof design, the large area available will permit several distant pattern ranges. It is planned to have a separate range for each of the most commonly used frequencies. Special pattern-measuring equipment and other electronic equipment has been designed by Workshop engineers to further complement laboratory facilities. Complete mechanical test facilities to meet the most exacting specifications will be included also.

Magnetic Track on 16-Mm Film Simplifies Home Sound Movies

The new 16-millimeter magnetic sound projector made by the Radio Corporation of America (RCA) provides the first means of directly recording commentary or musical background magnetically on the edge of 16-millimeter picture film. The new machine not only reproduces magnetic sound but also can be used to reproduce optically recorded sound.

Requiring no special preparation or studio facilities, three main features of the equipment make it possible for nonprofessional users to obtain excellent results in magnetic recording: 1. to record it is necessary only to turn a switch and talk or play music into a plug-in microphone; 2. after the recording is completed, another control may be set for immediate playback; 3. if revisions are needed or if rerecording of the film is desired, an electronic erase head may be activated by another simple control.

A mechanical safeguard prevents accidental erasing. The new recording technique is expected to find many applications in films designed for industry, schools, medical education, advertising, military, and government agencies.

High-Intensity Illuminator Extends X-Ray Film Usefulness

An iris-diaphragmed, high-intensity viewer that allows study of the widest range of X-ray film densities ever possible in the industrial field is announced by the General Electric Company, X-Ray Department, Milwaukee, Wis.

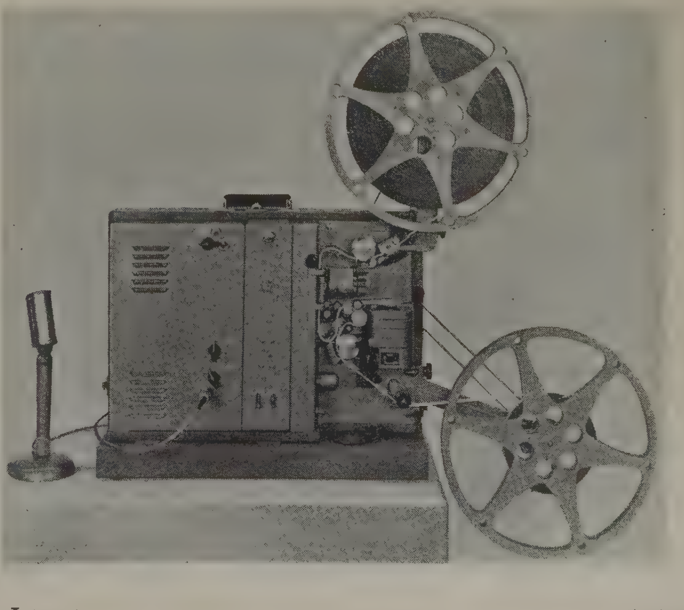
The wide range of viewable densities is made possible by two features: 1. the fact that the opening can be dilated steplessly or contracted, like a cat's eye, from a 1/4-inch triangle to a 5-inch diameter circle, thus concentrating the light on the area in question; 2. a special new 100,000-candlepower lamp is used, with an average life of 1,000 hours at the rated voltage, 115 volts. This compares with 6 to 10 hours' life for the average photoflood lamp. An even greater candlepower can be obtained by raising the voltage to 135, though this overload does shorten lamp life.

Film densities of from 0.5 to 4.5 can be penetrated by the new illuminator. This enables the radiographer to diagnose an object of greatly varying thicknesses with only one exposure. It also eliminates the need for retakes on overexposed films. To see through such films merely requires turning up the light intensity.

Recessing of the controls behind the surface of the illuminator makes it possible to move the radiograph to view any area desired without accidentally touching the controls. Use of a footswitch leaves both hands free for manipulating the radiograph.

Wall Thickness Gauge Speeds Up Quality Control Work

A precision gauge to determine the exact wall thickness and concentricity of lengths of tubing has been developed by the Quality Control Department, Fairchild Engine and Airplane Corporation, Hagerstown, Md. This electronic wall thickness gauge was built in response to the need for a method of



The new RCA magnetic sound projector with built-in magnetic recording equipment

This new wall thickness gauge developed by the Fairchild Engine and Airplane Corporation is able to determine wall thicknesses and concentricity of tubing up to 6 feet or more in length. The difference between two vernier micrometer readings gives the actual wall thickness accurate to 0.001 inch

determining wall thicknesses of tubing up to 6 feet or more in length to assure the maintenance of blueprint callouts and tolerances. Straight and tapering tubes can be checked with equal facility.

In several cases the new gauge has been utilized to solve practical production problems and has resulted in the saving of production man-hours and quantities of material which, without a means of accurate determination of wall thickness, would have had to be scrapped.

The new gauge consists of an arrangement of two horizontal arms mounted on a base. Wiring attaches contact points on the arms to an electronic 100-volt control box with transformer, amplifier, relay, and light for visual and horn for audio indication.

In operation, the test specimen is slipped over the lower arm of the gauge and cradled on V blocks. A screw adjustment permits zeroing the arm until a contact point touches the inside wall of the tubing. A vernier depth micrometer, resting on the end of the upper arm, is screwed down until it touches the outer surface of the test tubing.

While an electric current is sent through the arms, completing the circuit at the contact points, two readings of the vernier are taken, one with the tubing in place, the second with it removed and the vernier touching the lower contact point. The difference in the two readings is actual wall thickness, accurate to 0.001 inch.

The gauge not only measures the wall thickness of tubing at any given point but can be used to determine the concentricity of outer and inner surfaces, a valuable factor in over-all quality assessment of the tubing.

Tape Recorder Has 100-Kc Range to Pick Up Telemetering Data

A new magnetic tape recorder, especially designed for recording signals telemetered from aircraft and missiles, is announced by the Ampex Electric Corporation, Redwood City, Calif. It is the second of a line of special recorders designed for recording original telemetered data. The new recorder has a frequency range of from 100 to 100,000 cycles per second, thereby permitting the recording of all frequency-modulation–frequency-modulation telemetering channels recommended by the Telemetering Panel of Research and Development Board.

The new recorder is designed for three tape speeds: 60 inches per second in addition to the usual 30 and 15 inches per second. The major applications will be in the recording of frequency-modulated signals which contain measurement data made on aircraft or missiles during flight which must be recorded on the ground.

The extended frequency range of this unit makes it useful for recording many types of data which previously could be recorded only by means of a cathode-ray oscilloscope and moving film camera.

Oak Ridge Institute Offers Graduate Fellowships for 1952–53

The Oak Ridge Institute of Nuclear Studies is now receiving applications for Atomic Energy Commission Graduate Fellowships in Radiological Physics for the 1952–53 school year.

The fellowships are awarded for study at two training centers: one at the University of Rochester, Rochester, N. Y., in co-operation with Brookhaven National Laboratory, and the other at Vanderbilt University, Nashville, Tenn., in co-operation with Oak Ridge National Laboratory. In both cases, the final three months of the fellowship will be spent at the national laboratory. Appointments are made for one year for specialized training in radiological physics.

The annual basic stipend is $1,500. An additional $500 is allowed for a wife and $250 for each of two dependent children, making a maximum stipend of $2,500 annually. University tuition and fees will be paid by the Oak Ridge Institute of Nuclear Studies.

Applicants to be considered must hold an undergraduate degree at the time of entering the fellowship period, preferably with a major in physics, chemistry, or engineering, and a minor in mathematics, biophysics, or similar fields. Fellows must be citizens of the United States and must receive security clearance in accordance with existing laws.

Application blanks and additional information may be obtained from the heads of science and engineering departments of colleges and universities or from the University Relations Division, Oak Ridge Institute of Nuclear Studies, P. O. Box 117, Oak Ridge, Tenn. Applications must be in the hands of the Institute by March 1, 1952.

Light-Current Performance of Air Circuit Breakers Improved

An auxiliary air puffer applied to the high-capacity air circuit breaker provides a brief puff of air across the contacts as they separate and thereby decreases the low-current interrupting time. Without puffers, these circuit breakers, made by the Westinghouse Electric Corporation, break large currents more quickly than small ones. At small currents the magnetic forces are too weak to drive the arc into the interrupter. The puffer hurries the arc along. The puff of air is provided by a piston moving in a cylinder as the contacts separate. The puffer, never used before on this class of circuit breaker, is effective in reducing the interrupting time for all currents from 0 to 1,000 amperes, and insures interruption for all currents within the standard 8 cycles. The circuit breaker is well suited to 2.4- and 4.0-kv distribution circuits, and for powerhouse auxiliaries, particularly those supplied through cables that provide difficult-to-interrupt charging currents.

The circuit breaker can be equipped with a spring-powered closing mechanism for those applications where there is no battery and it is not convenient to provide one. Use of a manually operated closing lever is not positive enough or fast enough in case the circuit breaker is closed against a system fault. The hand-compressed spring provides ample energy for the task.

Giant Synchro-Cyclotron in Operation at Carnegie Tech

Carnegie Institute of Technology's $2,500,000 synchro-cyclotron is now in operation. Carnegie scientists have observed protons of energy of about 400,000,000 electron volts. Mesons also have been produced. Mesons are particles which until a few years ago had been found only in cosmic rays, those radiations which come to us continually from outer space.

Although the exact nature of mesons is not understood, there is considerable experimental as well as theoretical evidence that the existence of mesons is associated with nuclear force—that force which holds the nuclei of complex atoms together and keeps them from blowing up under the action of repulsive electric forces.

Critical data now known on the mesons are as follows: mesons weigh about 274 times as much as electrons or about 1/7 as much as protons, the heavy charged particles found in all nuclei. Protons are also the nuclei of hydrogen atoms. Some mesons have an electric charge equal to that on the proton or electron, either positive or negative in sign. Other mesons have no charge at all. Unlike protons and electrons, which have an intrinsic angular momentum (called by physicists 'spin'), mesons have no spin.

A unique property of the meson is that the mathematical wave function that describes it in the language of quantum mechanics is pseudo-scalar. This means that unlike the more familiar protons and electrons, the mathematical expression for the meson changes from positive to negative when the transformation of reflection is made in a co-ordinate system.

In simple terms, this property may be thought of as similar to one possessed by a glove which changes from a left-handed one to a right-handed one when seen in a mirror. The more familiar particles behave more like spinning tops which look the same on either side of the mirror.

The Carnegie Technology mesons are observed in special photographic plates placed near the synchro-cyclotron when it is in operation. These plates then are developed and examined under a high-power microscope.

Small tracks of about 4/1,000 inch in length are seen in these plates showing where mesons have passed through and made a developable image. A most characteristic feature of these meson tracks is that they sometimes end in a nuclear explosion or star.

A suitable site for the cyclotron was found in 60 acres of the Westinghouse Electric Corporation's property at Saxonburg, Pa., former *KDKA* first transmitting station area. On March 12, 1948, ground was broken for the Nuclear Research Center of Carnegie Institute of Technology.

The center now provides approximately 22,000 square feet of floor space for laboratories, a machine shop, offices, cafeterias, dormitories, and the synchro-cyclotron room.

14 Dutch Specialists Visit U. S. Electrical Industries

Fourteen specialists from The Netherlands' electrical and telecommunications appliances industries are in the United States to make a 5-week study of American plants in these industries under the productivity and technical assistance program of the Economic Co-operation Administration (ECA).

Upon its return to The Netherlands the group will make a report of its findings to the Dutch electrotechnical industry. ECA is sharing costs of the trip with The Netherlands. Team members were chosen from labor, management, and technical elements of the industry, so that a well-rounded view of the subject would be assured.

D. L. Putt Receives Award from Carnegie Institute

Major General Donald L. Putt, Acting Deputy Chief of Staff, Development, Headquarters United States Air Force (USAF), has received the Carnegie Institute of Technology Distinguished Service Achievement Award for outstanding service and accomplishment in the United States Air Force.

A 1928 Carnegie graduate with a Bachelor of Science degree in electrical engineering and a Master of Science degree in aeronautical engineering from California Institute of Technology, General Putt received the award for his outstanding contributions in research and development activities. Included was his development work on the B-17, B-25, B-26, B-29, and B-36 aircraft, together with the necessary modifications to convert the B-29 as the A-bomb carrier, while serving as Chief of the Bombardment Branch at Wright Field.

General Putt served overseas as Director of Technical Services for the Air Technical Services Command in Europe during World War II where he acted as the technical eyes and ears for the Air Force in Europe.

Following cessation of hostilities in Europe, General Putt returned to Wright Field to serve as the Deputy Commanding General, T-2 (Air Technical Intelligence) to administer and supervise the program of processing, screening, recording, and evaluating all air technological information obtained from Germany and Japan. The bulk of this information was subsequently disseminated to American industry to effect an undeterminable saving in funds and American research effort.

In April 1951 he was assigned as Assistant Deputy Chief of Staff, Development in Headquarters USAF, and subsequently was also made Acting Deputy Chief of Staff, Development.

In the near future General Putt will become Deputy Commanding General, Headquarters Air Research and Development Command at Baltimore, Md.

U. S. National Commission for UNESCO to Hold Conference

The Third National Conference of the United States National Commission for UNESCO will be held at Hunter College, New York City, January 27–31, 1952. The purpose of the conference is to assist a group of leaders, broadly representative of American life, in developing ways to improve our understanding of and participation in world affairs, particularly through the United Nations and the specialized agencies.

The delegates, who will number approximately 2,000, will divide into groups according to their special interests to consider various programs of international co-operation.

An engineering exhibit is being organized by the Engineers Joint Council representative for the conference and the participation of engineers as panel member discussors in the program for January 28 and 29 has been arranged.

Resistance Welder Manufacturers' Association Sponsors Contest

Announcement has been made of cash prizes to be awarded in 1952 by the Resistance Welder Manufacturers' Association for outstanding papers dealing with resistance welding subjects. The total amount of the awards is $2,250, the first prize being $750. For author or authors to be eligible for this award, their paper shall describe clearly original work done by them or under their supervision on resistance welding in any of its aspects by any method or process.

Further information on the contest may be obtained from the Resistance Welder Manufacturers' Association, 1900 Arch Street, Philadelphia 3, Pa.

NEW BOOKS • • • • •

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

BUSINESS AND PROFESSIONAL SPEECH. By L. Crocker. Ronald Press Company, New York, N. Y., 1951. 463 pages, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, $4.00. A detailed treatment of the basic aspects of speaking before an audience or group, covering grammar, selection of material, presentation of ideas, and so forth. Part II presents examples of common types of business and professional speeches. Appended are a bibliography and a section on suggestions to teachers.

(THE) CLASSICAL THEORY OF FIELDS. By L. Landau and E. Lifshitz, translated from the Russian by M. Hamermesh. Addison-Wesley Press, Cambridge 42, Mass., 1951. 54 pages, diagrams, $9^{1}/_{4}$ by 6 inches, cloth, $7.50. A translation from the original Russian, this book is part of a course in theoretical physics and gives a systematic presentation of the theory of electromagnetic and gravitational fields. The discussion is limited to "microscopic electrodynamics," the electrodynamics of the vacuum and of point charges, and is related to a number of topics: the propagation and polarization of light; diffraction; electromagnetic vibrations and radiation; the action of a particle in a gravitational field. The general theory of relativity is also dealt with.

COMBUSTION, FLAMES AND EXPLOSIONS OF GASES. By Bernard Lewis and Guenther von Elbe. Academic Press, Inc., New York, N. Y., 1951. 795 pages, charts, tables, illustrations, $9^{1}/_{2}$ by $6^{1}/_{2}$ inches, cloth, $13.50. Part I of this extensive treatise deals with the chemistry and kinetics of the reactions between oxygen and the following fuel gases: hydrogen, carbon monoxide, and various hydrocarbons. Part II, comprising about one-half of the text, provides an exhaustive treatment of flame propagation, covering combustion and detonation waves, ignition, fuel-jet combustion, and flame photography. Part III examines the state of the burned gas, and Part IV discusses the relation of the foregoing to a variety of technical combustion processes such as industrial heating and internal-combustion engines.

CORROSION GUIDE. By E. Rabald. Elsevier Publishing Company, New York, N. Y.; Amsterdam, The Netherlands; London, England; Brussels, Belgium, 1951. 629 pages, illustrations, diagrams, charts, tables, 10 by $6^{1}/_{2}$ inches, cloth, $12.50. The major part of this practical reference work is composed of tables showing the interaction phenomena between more than 40 important construction materials (metallic and nonmetallic) and some 250 corrosive agents. The object is to provide the chemist or engineer with readily usable information in the choice of materials for laboratory or industrial processes. Corrosion fundamentals are discussed in an introductory section, and a table of the physical properties of the materials involved is provided. A bibliography lists important books and periodicals.

DESCRIPTIVE GEOMETRY, a Pictorial Approach. By H. B. Howe. Ronald Press Company, New York, N. Y., 1951. 332 pages, illustrations, diagrams, charts, tables, 9 by 6 inches, linen, $4.00. Using the direct method of approach rather than the trace-of-plane method, this new text emphasizes the pictorial aspects as an aid to the engineering student in the solving of original problems. In line with this treatment two chapters are devoted to applications such as mining problems, construction details, wire and piping layouts, and so forth. The representation of lines, planes, vectors, simple and warped surfaces, intersections, and perspective are covered in full detail.

L'ECLAIRAGE PAR FLUORESCENCE. By R. Cadiergues. Dunod, Paris, France, 1951. 319 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by $6^{1}/_{4}$ inches, linen, 1,980 frs. Covers all aspects of the field of fluorescent lighting: theory, characteristics, circuits, and operating conditions for fluorescent tubes; fixtures and mounting methods; detailed information on the design and operation of lighting systems using fluorescent tubes. Tables of technical data are included throughout the text in the sections to which they are pertinent.

ENGINEERING GRAPHICS. By J. T. Rule and E. F. Watts. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 298 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $3.75. This text presents the study of engineering drawing in a broader manner than usual. Emphasis is placed on the use of graphical methods for the analysis of engineering problems. Methods of construction of conic sections, roulettes and spirals, graphical scales, empirical and periodic curves, and projective constructions are considered with simple applications to numerical problems. The latter part of the book is devoted to the customary elements of machine drawing which underlie normal drafting room practice.

ESSENTIALS IN PROBLEM SOLVING. By Zuce Kogan. From the author, 724 Sheridan Road, Chicago 13, Ill., 1951. 79 pages, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, paper, $3.00. The author discusses and gives practical examples of problem solving in which the specific problem is related to a generalized class of problem characteristics for which there is a generalized solution. From this the specific solution is then derived.

FUEL OIL MANUAL. By P. F. Schmidt. Industrial Press, New York, N. Y., 1951. 160 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, leather $3.50. Intended for both the seller and user, this manual provides a working knowledge of the characteristics of fuel oil and guidance in its effective use. A chapter is devoted to each of the various important properties with information concerning its relation to the selection, handling, and burning of the oil. Impurities, standard treatments, transportation, and storage are covered. The presentation has been kept as simple as possible, with a minimum of technical explanation and terminology.

(THE) HANDBOOK OF MEASUREMENT AND CONTROL. Edited by M. F. Behar and Associates. Instruments Publishing Company, 921 Ridge Avenue, Pittsburgh, Pa., 1951. 291 pages, illustrations, charts, tables, $11^{1}/_{4}$ by $8^{1}/_{4}$ inches, linen; included in subscription to "Instruments," $3.00 per year. This handbook is designed to provide users, manufacturers, and students with classifications, operating factors, and typical applications of instruments. The term "instruments" includes all indicating, recording, integrating, controlling, and computing devices used in measurement, inspection, testing, and control applications. Laboratory, scientific, engineering, and industrial instruments are included. Although detailed discussion of physical fundamentals is not attempted, all basic methods and mechanisms are covered including pneumatic, hydraulic, electric, and electronic.

MAGNETIC MATERIALS. By F. Brailsford. John Wiley and Sons, New York, N. Y.; Methuen and Company, Ltd., London, England. Second edition revised, 1951. 156 pages, diagrams, tables, $6^{3}/_{4}$ by $4^{1}/_{4}$ inches, fabrikoid, $1.50. This small book, like the others in the series of which it is a part, is intended to give a comprehensive outline of the present state of knowledge of the subject. The several chapters deal respectively with the following: ferromagnetism; properties and theory of single crystals; factors affecting magnetic properties; iron and silicon-iron alloys; nickel-iron and other alloys; and permanent magnet materials.

MATERIALS HANDBOOK. By G. S. Brady. Seventh edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 913 pages, illustrations, tables, maps, charts, $9^{1}/_{4}$ by 6 inches, fabrikoid, $8.50. This standard reference work gives practical data on approximately 9,000 materials arranged under several hundred major headings. The condensed information gives chief characteristics, sources, comparative data, uses, and so forth. There are a detailed 50-page index and a supplementary section giving basic information on weights, measurements, physical property ranges, definitions, and various useful tables. As with the successive previous editions, additional material and topics have been included to keep the contents up to date.

(THE) NEW MILITARY AND NAVAL DICTIONARY. Edited by F. Gaynor. Philosophical Library, 15 East 40th Street, New York, N. Y., 1951. 295 pages, charts, tables, maps, $9^{1}/_{4}$ by $6^{1}/_{4}$ inches, linen, $6.00. A comprehensive and definitive glossary covering all branches of the armed forces such as technical terminology, organizations, and personnel details. The more than 7,000 terms include the latest available and unclassified data pertaining to guided missiles and rocketry, atomic and radioactivity weapons, chemical warfare, and the various electromagnetic ranging and detecting systems.

PRODUCTION AND INVENTORY CONTROL. By W. E. Ritchie. Ronald Press Company, New York, N. Y., 1951. 278 pages, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, $5.00. Avoiding other engineering and manufacturing activities involved in running a plant, this text centers on the systems required to control production operations and inventory levels under various manufacturing conditions. Following the general discussion of the subjects involved are detailed explanations of representative systems illustrated by representations of operating forms in actual use in a wide variety of business organizations.

QUALITY-CONTROL HANDBOOK. Edited by J. M. Juran. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 800 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $10.00. The first half of this comprehensive volume covers the economics and specification of quality, how to organize for quality, the acceptance, control, and assurance of quality, statistical methods in the quality function, and forms and records for quality-control procedures. In the second half, applications to specific processes and products are described by specialists in textile production, chemical process industries, aircraft manufacture, electron tubes, and screw-machine operations. Illustrative examples from actual cases provide practical working information. There are also chapters on the applications of electric accounting machines to quality control and on an improved procedure for sampling inspection of any material.

(THE) RESTLESS UNIVERSE. By M. Born. Dover Publications, New York, N. Y., 1951. 315 pages, illustrations, diagrams, charts, tables, $9^{1}/_{2}$ by 6 inches, linen, $3.95. Intended to provide the layman with a simple, yet consistent, account of modern physics, this book deals with the nature and action of gases, with atoms, electrons, and ions, with wave mechanics and particles, and with the laws and developments of nuclear physics. Specially designed illustrations are included. In this new edition a "postscript" has been added discussing at considerable length the interaction between politics and science.

STANDARD MANUAL ON PIPE WELDING. Heating, Piping and Air Conditioning Contractor, National Association, Suite 1401, Rockefeller Center, New York, N. Y., 1951. 506 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $7.50. Written primarily for the piping contractor, this comprehensive manual contains material of value to the architect and engineer as well. Welding equipment and processes are described, and materials and filler metals are covered thoroughly. Shop organization is discussed, and space is devoted to layout and fabrication details, including templets and jigs. Other topics considered are cost estimating, testing and inspection, selection and training of operators, and the scope of pipe welding. Welding terms and symbols are listed, and necessary tables and formulas are included.

TABLES OF THE EXPONENTIAL FUNCTION e^x. United States Bureau of Standards, Applied Mathematics Series Number 14, 1951. 537 pages, tables, $10^{1}/_{2}$ by 8 inches, buckram, $3.25, for sale by Superintendent of Documents, United States Government Printing Office, Washington, D. C. Tables of ascending exponentials in following ranges: 0.0000–1.0000 to 18 decimals, 1.0000–2.5000 to 15 decimals, 2.500–5.000 to 15 decimals, and 5.00–10.00 to 12 decimals; descending exponentials 0.0000–2.5000 to 18 decimals; ascending and descending exponentials 0.000000–0.000100 to 18 decimals, 1–100 to 19 significant figures, and 1×10^{-10} to 9×10^{-7} to 18 decimals; values of e and $1/e$ to 2,556 decimals.

THEORY OF ELASTICITY. By S. Timoshenko and J. N. Goodier. Second edition. McGraw-Hill Book Company, New York, N. Y.; Toronto, Ontario, Canada; London, England, 1951. 506 pages, illustrations, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, linen, $9.50. The theory of elasticity must be used where the elementary theory of strength of materials proves insufficient, as in dealing with local stresses near loads and supports and in regions of sharp variation of cross section. This book presents the fundamentals of that theory with special reference to the needs of the engineer. The presentation considers both 2- and 3-dimensional problems. Photoelastic, soap-film, and other experimental methods are included. The additions and revision of the current edition express the developments in the field during the 17 years since the previous edition was published.

PAMPHLETS • • • • •

The following recently issued pamphlets may be of interest to readers of "Electrical Engineering." All inquiries should be addressed to the issuers.

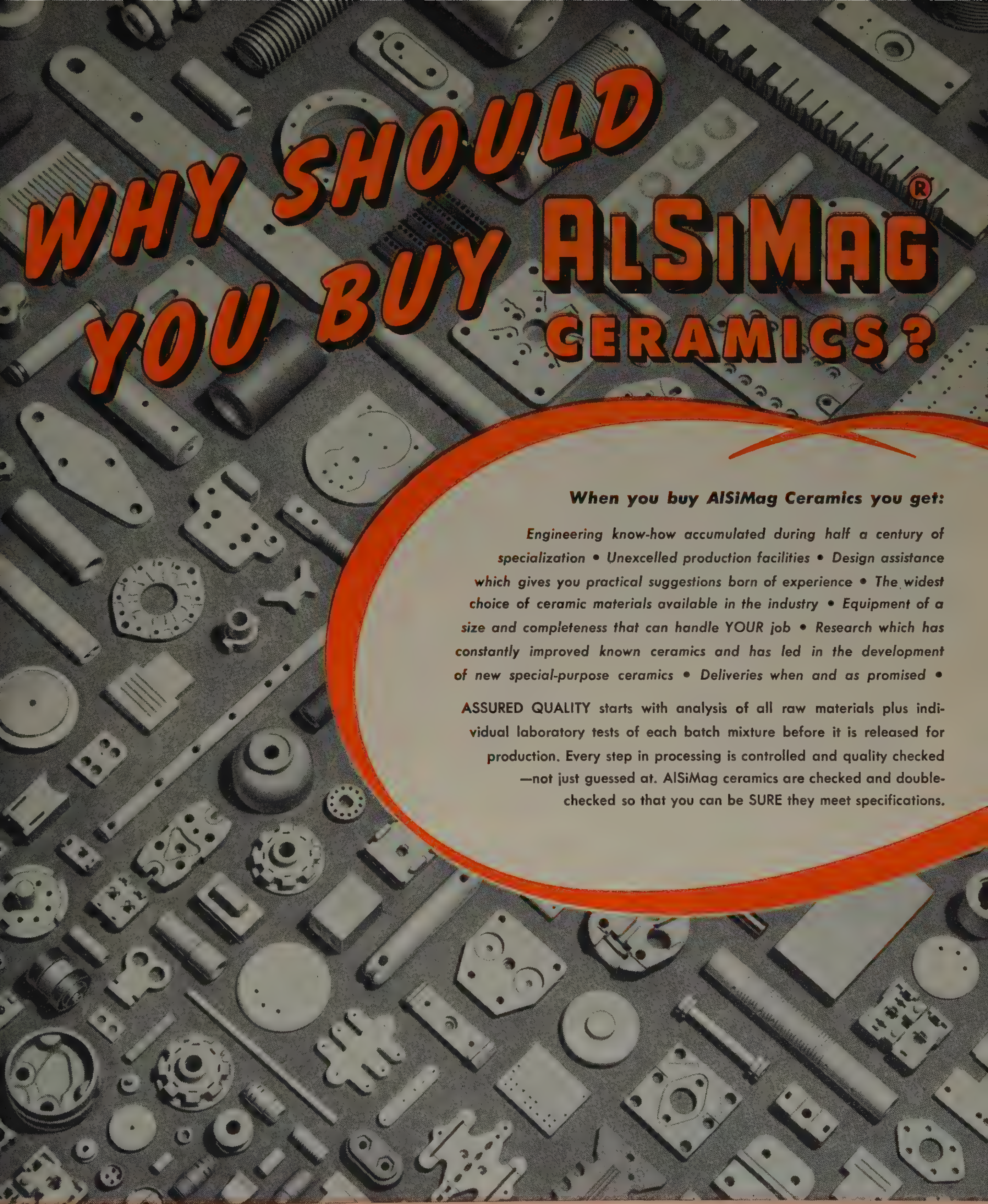
Metallizing Handbook. Comprehensive coverage of the technical as well as the practical aspects of the process. Various methods of surface preparation and the application of metallized coatings for machine element work, for corrosion work, and for many special production jobs are detailed. Illustrated with photographs, diagrams, and charts. 250 pages. $3.00 per copy. Published by Metallizing Engineering Company, Inc., Long Island City, N. Y.

Training by Television. This report, a study in learning and retention, evaluates the use of television for rapid teaching of large numbers of men. Eight lessons were telecast at weekly intervals to more than 3,000 Army Field Force Reservists. The men were tested before and after each televised lesson. The tests were planned to find out not only how much was learned from the lesson just seen but how much was remembered from the previous lessons. An analysis of the various teaching methods used in each lesson led to the conclusion that the best method used was narrative combined with drama or film that defined and amplified what the narrator was talking about. 24 pages, $0.75 per copy. Available from the Office of Technical Services, United States Department of Commerce, Washington 25, D. C.

A Photoelectric Recording Interferometer for Measurement of Dimensional Changes. A method is given for the photoelectric recording of light intensity at a reference point in an image of an interference pattern for the automatic plotting of fringe count versus thermocouple electromotive force interferometric dilatometry. This report explains application of the technique to the measurement of coefficients of expansion and to the determination of transition temperatures in rubber-like materials over a temperature range of −185 to +185 degrees centigrade. $0.10 per copy. Available from the Superintendent of Documents, United States Government Printing Office, Washington, D. C.

A Review of Electrical Properties of Wood. Examination of wood's dielectric constant, dielectric loss factor, conductivity, and power factor on a basis of the underlying electrical theories involved. The review discusses variations in each property caused by frequency, temperature, moisture content, density, and direction of grain. $0.30. Published by State University of New York, College of Forestry, Syracuse, N. Y.

Dollar Savings Through Standards. Specific savings and production benefits directly attributed to standardization in American industry are cited. This report was prepared for the Economic Co-operation Administration to encourage European manufacturers to adopt United States production methods in order to speed military preparedness and to strengthen economic self-dependence. Obtainable for $1.00 from the American Standards Association, 70 East 45 Street, New York 17, N. Y.



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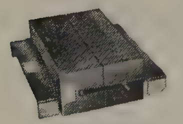
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INDUSTRIAL NOTES ....

Westinghouse Sales Soar, but Taxes, Higher Costs, Trim Net Income. Sales of the Westinghouse Electric Corporation in nine months of 1951 soared to a new record of $901,042,000, an increase of 23 per cent over a comparable 1950 period. However, the Westinghouse tax bill for the first nine months of 1951 amounted to $76,822,000 as against $37,885,000 in the like period of 1950, an increase of 102.9 per cent. Thus, net income after taxes for the first three quarters of this year was $42,757,000 as against that of last year of $49,079,000, despite the 23-per cent increase in sales.

Westinghouse has announced that two vice-presidents have been assigned new duties in a move designed to expedite the company's defense activities: L. E. Osborne, formerly Vice-President in charge of manufacturing, has been made Executive Vice-President—defense products, and Tom Turner, Vice-President in charge of labor relations becomes Vice-President in charge of manufacturing and labor relations. The company also has announced the appointment of Carl E. Albracht as manager of their western publicity division, with headquarters in San Francisco, Calif.

Allis-Chalmers Higher Earnings Affected by New Taxes. Record billings for the nine months of 1951 of the Allis-Chalmers Manufacturing Company were $320,354,570, an increase of 27 per cent over the same period of a year ago. Earnings before federal income and excess profits taxes for the nine months of 1951 amounted to $43,346,804, an increase of 36 per cent over the same period in 1950. However, because of increased tax rates (95 per cent) net income amounted to $15,696,804, as against $17,613,821 for 1950, despite the higher sales.

The company has announced the appointment of F. C. Ludington as manager of the Hawley Works in West Allis.

Du Mont Appointments. Rear-Admiral Stanley F. Patten, United States Navy (retired), has been elected Vice-President of the Allen B. Du Mont Laboratories, Inc.; William Carlin has been made manufacturing manager of the cathode-ray tube division; and the Elliott Equipment Company, 712 Sixth Avenue, South Minneapolis, Minn., has been named sales representative for the cathode-ray tube division. This new representative will cover jobbers in Minnesota and North and South Dakota.

Kerite Sales Engineer Killed in Accident. John R. Walsh, sales engineer for The Kerite Company, and his wife, died recently in an automobile accident.

G-E News. Sam Littlejohn has been elected Commercial Vice-President of the General Electric Company, with headquarters in Cleveland, Ohio; A. W. Bartling has been named manager of product sales practices, apparatus sales division, with headquarters in Schenectady, N. Y.; L. E. Newman has been made manager of marketing, Large Steam Turbine and Generator Department; Charles C. Ledin has been appointed product service engineer on the company's home laundry equipment; James R. Squires has been named manager of advertising and sales promotion for the Atlantic District, apparatus sales division, with headquarters in Philadelphia, Pa.; and H. C. Green and R. E. Wendling have been appointed district representatives for the construction materials division of the company.

The General Electric Company also has announced the retirement of Bernard C. Tracey, manager of accessories and renewal parts sales of the company's Welding Department. Mr. Tracey joined General Electric in 1918.

Emerson Electric Moves District Office. The Chicago District office of The Emerson Electric Manufacturing Company has moved to larger quarters at 1623–25 South Pulaski Road, Chicago 23, Ill. All warehouse and office operations are consolidated in the new and larger quarters.

United States Steel Elects Vice-President, Assistant. The United States Steel Corporation has elected Robert M. Lloyd Vice-President—raw materials, and has appointed Paul F. Kohlhaas as Assistant Vice-President—design and appropriation control.

Dr. Kelsey Heads Radiochemical Program at Nuclear Instrument. Dr. F. E. Kelsey has been appointed Director of Radiochemistry by the Nuclear Instrument and Chemical Corporation.

Sylvania Names International Sales Director. Frederic J. Robinson has been appointed Director of the international sales division of Sylvania Electric Products, Inc.

Executive Appointments at Servomechanisms, Inc. The extensive expansion program undertaken by Servomechanisms, Inc., has resulted in the following new appointments: J. A. Granholm, formerly Treasurer, has been made Executive Vice-President; C. H. Rodgers, formerly controller, has been made Treasurer; E. W. Kulesh, formerly manager, has been named Divisional Vice-President in charge of the Florida division; and H. R. Larsen, formerly manager of the West Coast division, California, has been appointed Divisional Vice-President.

Stackpole Appointment. H. A. Williams has been made manager of the Stackpole Carbon Company's electronic components division.

Lear Announces Executive Changes. Lear, Inc., has announced the following appointments: A. G. Handschumacher,

(*Continued on page 20A*)

All Allis-Chalmers installation: 250-hp, 495-rpm, drip-proof cage motor; single-stage rotary compressor; controller.

ALLIS-CHALMERS Large Motors

. . . Provide Low-Maintenance Reliability

START with construction features that have already earned a reputation for ruggedness and reliability. Add all-around drip-proof and mechanical protection. And do this without sacrificing accessibility for routine maintenance.

That's how Allis-Chalmers large cage motors were redesigned. That's why you'll want these advantages in your new motors:

IMPORTANT FEATURES

- Rigid cast-iron end shields assure you of correct bearing alignment and corrosion resistance as well as drip-proof protection.
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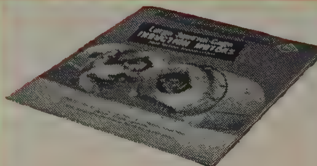
- Large air discharge openings in the yoke invite you to keep the ample passages back of the stator core clean and unobstructed. They also make installation easier.
- Louvers on air discharges and design of intakes keep foreign objects out of the motor.

A-3561



NEW BULLETIN

Built in ratings from 60 hp at 300 rpm to 1750 hp at 1800 rpm, these cage motors are described in detail in bulletin 05B7542A. Ask your nearby Allis-Chalmers representative for a copy, and see for yourself why these redesigned motors provide a new low in maintenance and a new high in reliability. Allis-Chalmers, Milwaukee 1, Wisconsin.

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3 No rivets, eyelets, screws or solder
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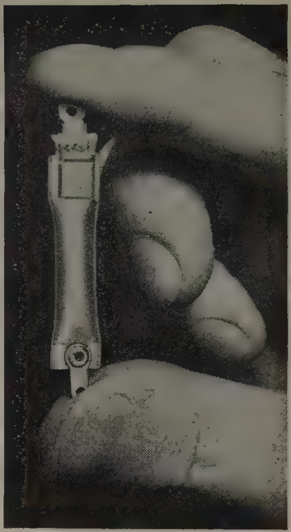
5 Low installation cost
6 Pre-calibrated to fit exact product needs
7 Adaptable to your present design
8 Fast, simple production assembly



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217 ASH STREET AKRON 2, OHIO

(*Continued from page 16A*)

Vice-President, has been made general manager of the Grand Rapids, Mich., division; W. Dawkins Espy, Vice-President, has been named chief engineer of that same division; George K. Otis has been made general manager of the LearCal division; A. H. Endlekofer replaces James Wood as works manager of the Grand Rapids plant; A. N. Lawrence has been placed in charge of the contract division at Grand Rapids, replacing leMoyne Dabbs, now manager of the eastern division office at Teterboro, N. J.; and Richard H. Stewart has been named quality control manager.

Barto Made Vice-President of Rodale. Elmer A. Barto has been made a Vice-President of the Rodale Manufacturing Company, Inc.

Strux Appointment. Paul John Witte has been named Executive Vice-President of the Strux Corporation, Hicksville, L. I., N. Y. This company has taken over production of cellular cellulose acetate (CCA) from the Aircraft Specialties Company, Inc. CCA was developed and manufactured by E. I. du Pont de Nemours and Company, and is now manufactured by the Strux Corporation under license from duPont.

Magnethermic Corporation Opens New Plant. The Magnethermic Corporation, organized four years ago in Youngstown, Ohio, has announced the opening of its new plant at 3990 Simon Road.

Lenkurt Installs Stratosphere Test Chamber; Appointment. The Lenkurt Electric Company, designer and manufacturer of carrier telephone and telegraph equipment and other electronic apparatus, recently installed a stratosphere test chamber at its factory in San Carlos, Calif., in order to test the performance of their products under varying conditions of temperature, altitude, and humidity. The stratosphere chamber generates temperatures between −100 degrees Fahrenheit and +200 degrees Fahrenheit, with pressures that simulate altitudes as high as 80,000 feet.

The company has also announced the appointment of Maurice Harp to their engineering staff in the position of applications engineer for the development of frequency modulation and single-sideband space-carrier equipment.

U. S. Motors to Build $3,500,000 Plant. A $3,500,000 electrical motor manufacturing plant will be started in Orange County, Calif., in 1952 by U. S. Electrical Motors, Inc. An 85-acre site, 20 miles from Los Angeles, has been purchased. Construction will include a 50,000-square-foot administration building and 250,000 square feet of covered manufacturing area.

Continental Electric Elects Vice-President. Perry M. Green, Jr., has been elected a Vice-President in charge of

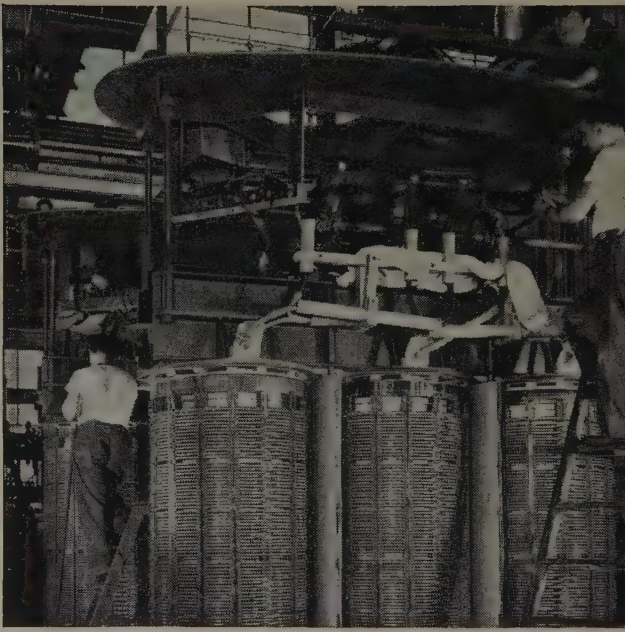
(*Continued on page 32A*)

OREGON UTILITY Boosts Capacity

ADDS THREE 6,000 KVA ALLIS-CHALMERS POWER TRANSFORMERS

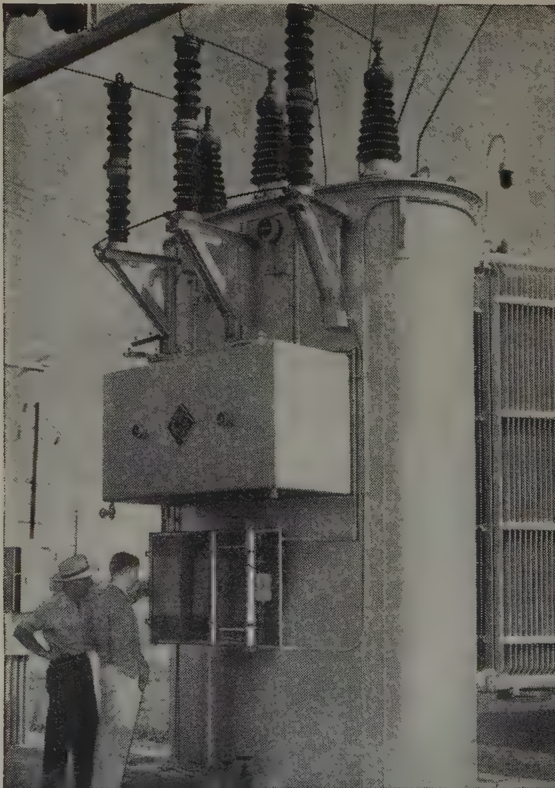
OREGON RESIDENTS use three times more power than the national average. Records show that 99% of the farms and suburban homes in the area served by the Portland General Electric Company are electrified. And Allis-Chalmers power, distribution and network transformers help PGE — the state's largest electric utility — distribute the power. These 6,000 kva transformers step up capacity for Salem, the capital city of Oregon.

Repeat orders from PGE — and from utilities across the country — are evidence that Allis-Chalmers power transformers are providing dependable, on-the-job service day in and day out. For more details call in your A-C sales representative, or write Allis-Chalmers, Milwaukee 1, Wisconsin. Offices in 64 principal cities. A-3542



GOOD WORKMANSHIP. Winding and core structure are securely supported and braced. Machine wound tubes, anchored in a sturdy clamping, support and insulate the leads. Good workmanship characterizes assembly work in all stages of transformer assembly.

VINDINGS ARE UNIFORMLY TIGHT. A battery of winding machines winds coils simul-aneously from a continuous conductor. This method maintains uniform tightness hroughout the winding process and eliminates internal connections. Spacers, uniformly paced and cemented between coils, give good support and promote coolant circulation.



MORE POWER. This 6,000 kva transformer is one of three Allis-Chalmers power transformers installed at Portland General Electric Company's Middlegrove substation to boost power capacity.

MAKE THIS YOUR HOME FOR IMPORTANT WORK UNDER IDEAL CONDITIONS

- TV RECEIVER DESIGN ENGINEERS
- ELECTRONICS ENGINEERS
- FIELD ENGINEERS
- TEST & INSPECTION ENGINEERS
- LAB. TECHNICIANS

NEEDED TO WORK ON: Radar, G.C.A., Mobile Radio, Auto Radio, Airborne Communication & Navigation Equipment, Television, Antennas, Microwave Equipment, Servo Mechanisms and Guided Missiles.

YOU BENEFIT AT BENDIX RADIO: from high wages, a modern, air-conditioned plant, paid vacations and holidays, group insurance and a good chance for advancement.

Housing immediately available in the beautiful suburban and country areas that surround the Bendix Radio plant.

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48 Carbon Black Plants
203 Metallurgical Installations
205 Acid Plants • 40 Paper Mills
270 Detarring Installations
216 Power Stations
73 Steel Plants • 99 Oil Refineries
and Miscellaneous Installations

Your electrical precipitator installation will be individually engineered...and based on the Research Corporation's *experience* graphically shown by that towering pile of thousands of blue prints.

This knowledge is a valuable asset that will help Research engineers to "tailor-make" your Cottrell installation. For example, they can more quickly determine the right answers to such variables as the size, shape and type of both discharge and collecting electrodes, their relative spacing, flue arrangements and many other factors. At Research you can count on *profitable solutions to individual problems.*

Research Corporation Cottrells can be made as efficient as you desire. They can collect 95% to over 99% of all solid or liquid particles suspended in gas entering equipment. Write for free booklet giving valuable data.

Typical One Day Collections

- 250 TONS OF FLY ASH
- 5500 POUNDS OF CONCENTRATED SULPHURIC ACID
- 6 TONS OF SODA SALTS AT PAPER MILL

RESEARCH CORPORATION
405 Lexington Ave., N. Y. 17, N. Y. 122 S. Michigan Ave. Chicago 3, Ill.

(Continued from page 20A)

production of the Continental Electric Equipment Company.

Borg-Warner Appointments. Robert J. Minshall has been made President and general manager and G. V. Patrick has been named Vice-President and assistant general manager of the Marvel-Shebler Products Division of the Borg-Warner Corporation. These appointments were necessitated by the retirement from the presidency of S. W. Gray.

NEW PRODUCTS • •

Atomic Battery. The Ohmart Corporation has announced the development of an atomic battery in which an electric current is generated directly from radioactivity. These atomic batteries are finding their first application in a new line of precision gamma activity measuring instruments which require no high-voltage power supply, since the energy in the radioactivity is itself utilized to produce the electric current. Geometrical error is reduced by having the cells so arranged that samples are placed within the cells in approximate 4-pi geometry. Only one vacuum tube is required. Future plans of the company include development and manufacture of a new type of personnel dosimeter, a contamination monitoring device to be used in conjunction with water works installations, and a new type of liquid level gauge. Further information on these new developments may be obtained directly from the Ohmart Corporation at 2347 Ferguson Road, Cincinnati 28, Ohio.

Time-Delay Plug Fuse. A new type of shock-absorber safety glass-top plug fuse has been introduced by the Royal Electric Company, Inc., 95 Grand Avenue, Pawtucket, R. I. Incorporating a time-delay "lag" link of a new type, the fuse will safely absorb starting overloads and sudden current surges, just as cartridge-type lag fuses do, preventing needless blowing, but giving ample protection to the entire circuit. Further information may be obtained from the company.

Electronic Totalizers. High-speed counting at near ultrasonic rates is available with two new models of detectron electron totalizers, developed by the Stratex Instrument Company, 1861 Hillhurst Avenue, Los Angeles 27, Calif. Typical applications are in hydraulics, pneumatics, stress analysis, nuclear physics, aerodynamics, missile design, and in the determination of production and flow rates in the processing and fabricating industries. Model *TU-9* automatically records impulses up to 30,000 per second, while *TU-100* will record at rates as high as 100,000 per second. Both units are provided with octal base plugs for individual or series mounting in conjunction with other equipment or circuits. By cascading a series of units, direct readings of near astronomical proportions can be made. Power supply is 200 to 400 volts d-c, at 12 milli-

(Continued on page 42A)

THIS IS A BUSHING PORCELAIN

Nothing unusual about it, nor complicated, nor difficult from a porcelain-maker's standpoint . . .

. . . Except for some "special" considerations. A smaller-than-usual porcelain bushing could contribute substantially to economy in the complete assembly . . . *if* the porcelain bushing could withstand some rather sharp mechanical impacts encountered in service . . . *if* the bushing could be mounted with a lead alloy instead of customary cement . . . and *if* the electrical reliability of the porcelain were certain.

That sounds easy. And it is . . . for Lapp. Yet Lapp porcelain was one of very few found which met this set of requirements. This piece in Lapp porcelain developed almost twice the strength of that of some other porcelains tested. It won't crack under the strain of lead mounting. And, like every piece of Lapp porcelain, each unit gets a high-safety-factor electrical test before shipment.

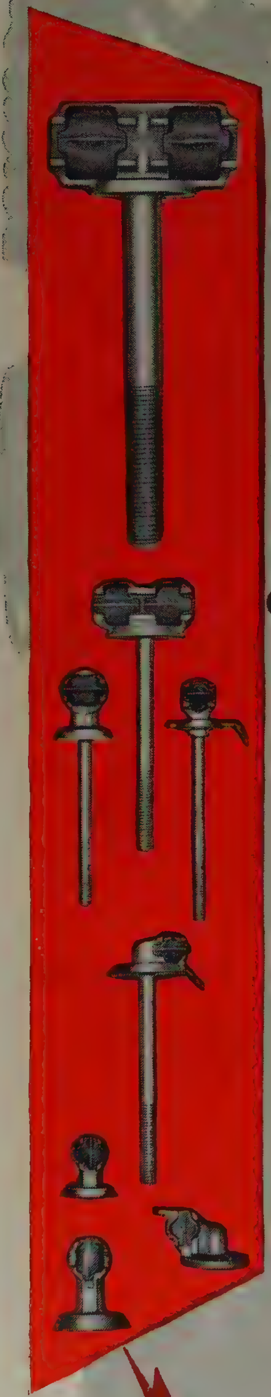
The manufacturer who uses this Lapp porcelain bushing in his product knows that he is offering extra value to his customers when he says *"Porcelain by Lapp."* Also he realizes production economies resulting from elimination of factory troubles, assurance of freedom from rejects, close adherence to mechanical specifications, and elimination of need for testing these parts. So, although he pays somewhat more per piece for porcelain of Lapp quality than he would for the cheapest porcelain he could buy, he finds he is getting a bargain in all-over cost, performance, and prestige.

Do you look for the name on the *porcelain* in equipment used on your system? When you find Lapp porcelain, you'll know that the manufacturer of that equipment is willing to give you "something extra" as a guarantee of dependable performance.

For . . . *you can buy cheaper porcelain . . . you can't buy better porcelain* . . . than Lapp.

Lapp Insulator Co., Inc., Le Roy, N. Y.

Lapp



TRANSFORMERS
and
CONNECTORS
Go Together For
YEAR IN
YEAR OUT
DEPENDABILITY

Specify
TRANSFORMERS EQUIPPED
WITH ABW MERCUROUS
NITRATE RATED
CONNECTORS . . .

For your protection against connector seasonal and stress corrosion cracking failures, exacting transformer manufacturers demand ultimate connector performance certified by mercurous nitrate test standards.

Perfection of connector designs has enabled Anderson Brass to surpass this ultimate of engineering requirements and as a result for many years we have furnished the major connector needs of the transformer manufacturers.

Routine mercurous nitrate testing in accord with specification ABW 124-1* is part of our quality control.

Our products are backed by many years of coordinated electrical, mechanical and metallurgical engineering knowledge and manufacturing experience gained in meeting and maintaining the most exacting standards of the electrical industry.

*Write today for mercurous nitrate test specification ABW 124-1

Consult one of our nearest 17 representatives or contact our main office

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POST OFFICE DRAWER 2151
BIRMINGHAM, 1, ALABAMA

• BRONZE AND ALUMINUM POWER CONNECTORS, FITTINGS, AND BUS SUPPORTS
ALUMINUM SUSPENSION AND STRAIN CLAMPS

(Continued from page 32A)

amperes, with an input-output pulse of 100 volts negative. Descriptive literature is available from the company upon request.

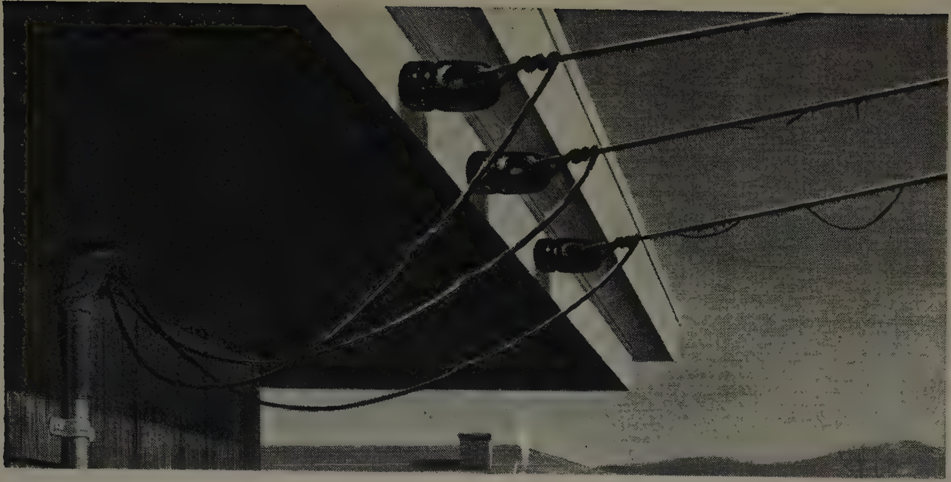
Carbon Soldering Process. A new process announced by the Stackpole Carbon Company, St. Marys, Pa., makes it possible to solder carbon to metal, thus gaining all of the advantages of carbon for contacts, small brushes, and friction devices. Costly fixtures formerly necessary for bolting or clamping the carbon units in place can be eliminated. For example, the new method permits welding carbon contacts directly to metal arms. Carbon brushes can be soldered to phosphor bronze or beryllium copper leaf springs, eliminating brush holders and shunts, and simplifying equipment design. Further details on this new process may be obtained from the Stackpole Carbon Company.

Low Level Potentiometer Circuit. A new potentiometer circuit that permits measurements of spans as narrow as 100 microvolts has been developed by the Minneapolis-Honeywell Regulator Company. These narrow-span instruments can be used wherever accurate measurements of d-c potentials of the order of microvolts is required. They are applicable for laboratory investigations and for production line measurements of low potential signals in the order of 0.1 microvolt. The instruments are also useful (with appropriate primary measuring elements) for the precise measurement of differential temperatures, and the accurate determination of slight variations in the temperatures of small objects through the use of radiation pyrometry. Additional applications embracing other variables reducible to d-c potentials also exist where the high resolution obtainable with narrow-span instruments facilitates precise measurement. Three styles of narrow-span instruments are available: the precision indicator; the circular chart recorder; and the strip chart style. Further details may be obtained from the Minneapolis-Honeywell Regulator Company, Brown Instrument Division, Wayne and Windrim Avenues, Philadelphia 44, Pa.

Outdoor Motor Control Instruments. New raintight outdoor motor control units are available from the Westinghouse Electric Corporation. Originally designed for use on irrigation projects, they are applicable to many other outdoor motor control jobs. The units consist of a combination across-the-line starter with circuit breaker in a raintight enclosure with raintight, built-in controls. Designated as class *11-206-NR*, these starters are available in five sizes. Standard voltages are 220 volts and 440 volts, 60 cycles, although with proper coils the starters are suitable for voltages up to 600 volts. For further information, write Westinghouse Electric Corporation, Box 2099, Pittsburgh 30, Pa.

Vibration Isolation Mount. A new center-of-gravity type vibration isolation

(Continued on page 46A)



WHY THREE?...

WHEN ONE IS BETTER!

Kaiser Aluminum triplex service drop cable combines *three* wires in a single cable. Thus you get all these advantages:

Cost savings—compared with copper weatherproof installations—of *20 to 40 per cent!* The reasons: Triplex needs fewer accessories—requires only one house knob. Permits longer spans—cuts maintenance—because light weight and low wind and ice loadings reduce tension on house and pole. And it's installed easier, faster.

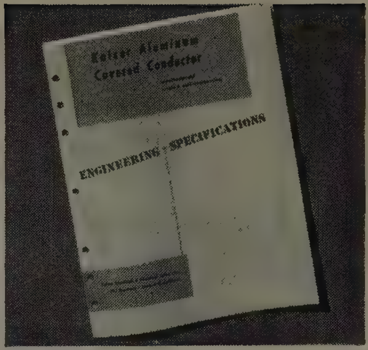
What's more, the single cable gives greater clearances, reduces contacts with trees, results in a far neater appearance.

Call us today for the facts! Sales offices in principal cities. Kaiser Aluminum & Chemical Sales, Inc., Oakland, California.

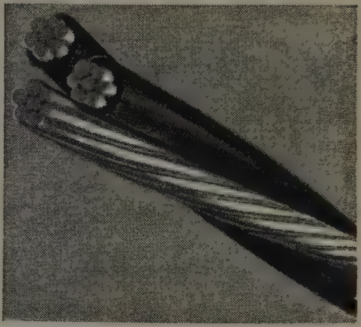
Also distributed by: General Electric Supply Corporation, Line Material Company, Mine & Smelter Company, Tafel Electric and Supply Company, Westinghouse Electric Supply Company.

Kaiser Aluminum

Setting the pace . . . through quality and service


Kaiser Aluminum Covered Conductor
ENGINEERING · SPECIFICATIONS

FREE BOOKLET—Gives complete engineering data on the new Kaiser Aluminum Conductor. Includes both weatherproof and self-supporting conductor. Send for it today!

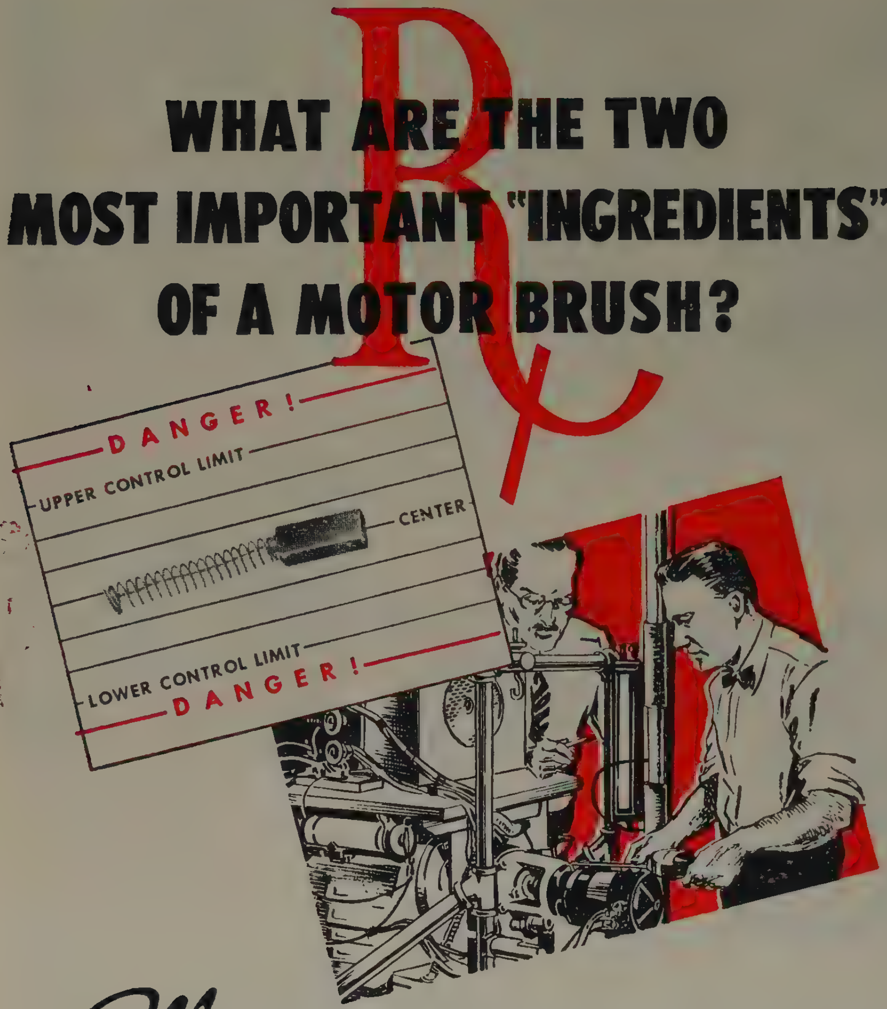


THREE-IN-ONE—Triplex is a single cable made up of three wires—two neoprene or polyethylene covered wires cabled about the bare neutral messenger. Coverings are light, free-stripping, clean to handle.

FOR SECONDARY LINES—In many cities Kaiser Aluminum triplex cable is now being installed in secondary lines. Aluminum duplex cable is being used on street lighting circuits.

TECHNICAL ASSISTANCE—Service engineers with years of experience in the conductor field will gladly provide technical assistance. Call any Kaiser Aluminum office. See your Classified Telephone Directory.

WHAT ARE THE TWO MOST IMPORTANT "INGREDIENTS" OF A MOTOR BRUSH?



Most small motor brushes are made from the same basic materials, on the same type of equipment, under much the same conditions. What then, makes one line of brushes so outstandingly superior to another for a given application?

Here at Stackpole, we're convinced there are two chief factors involved: (1) Laboratory Engineering by brush experts who produce a brush formula for the specific product involved under actual operating conditions and, (2) Statistical Quality Control that covers brush processing from the base materials through every step of manufacture. Characteristics are carefully controlled, maximum uniformity assured.

Long experience proves that, backed by these two basic Stackpole ingredients, almost any small motor brush performance can be materially improved.

Stackpole brushes are sold only to makers of original equipment

STACKPOLE

Write today for your copy of this helpful 44-page Brush Users' Guide

STACKPOLE CARBON CO
ST. MARYS, PA.

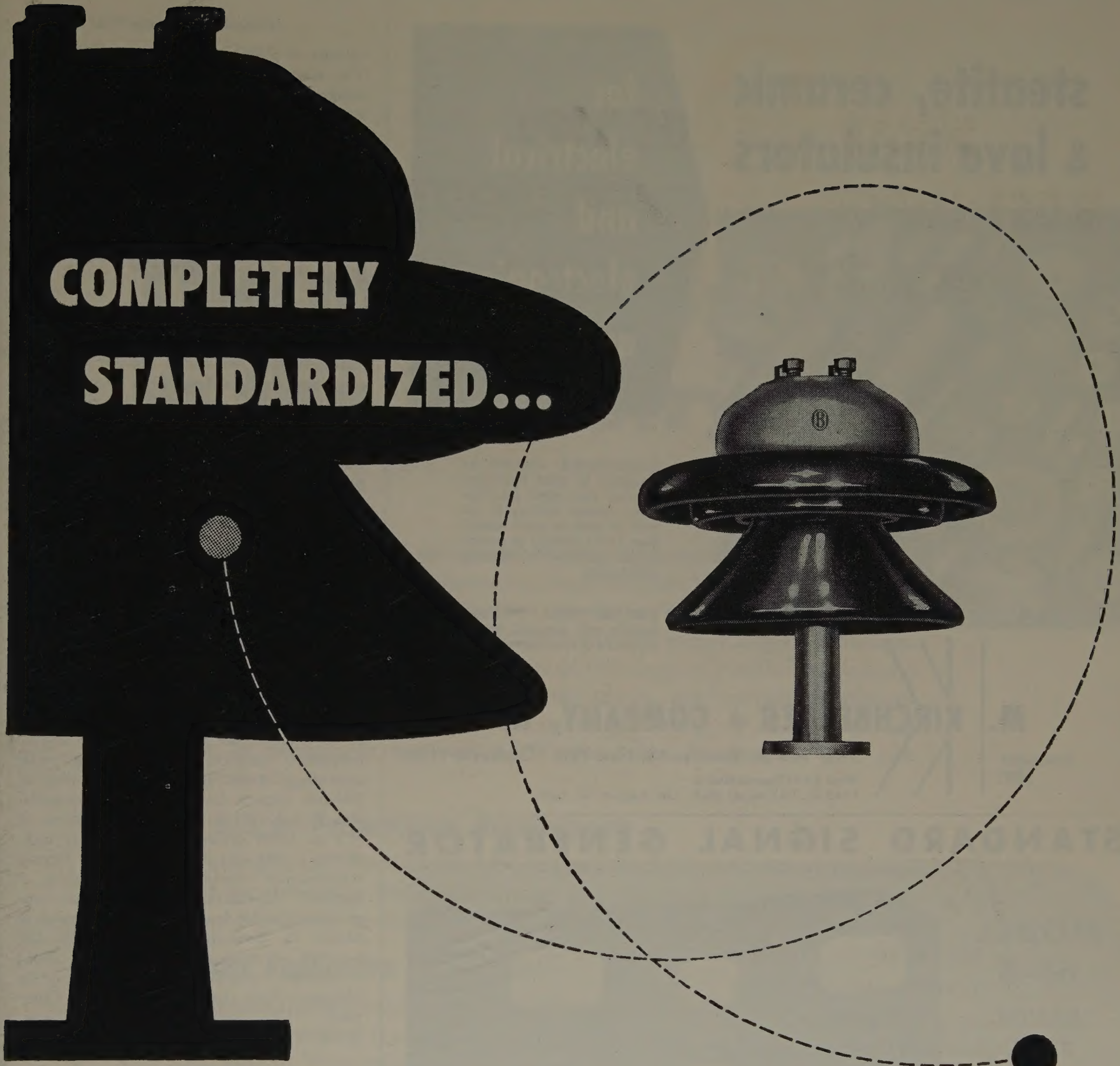
(*Continued from page 42A*)

mount has been developed by the engineers of General Electric's Control Department to protect aircraft voltage regulators from the effects of shock and vibration. Developed with the co-operation and assistance of the Navy Department Bureau of Aeronautics, the new mount is capable of withstanding a shock or sustained acceleration of 10 g's, and will absorb vibration deflections of 0.06 inch (total travel) when subjected to simple harmonic motion at frequencies of 10 to 55 cycles per second and amplitudes corresponding to 10 g's from 60 to 200 cycles. It also meets a 25-hour salt-spray test. Four phosphor-bronze laminated spiral springs with copper braid sleeves are located at the corners of a movable base so that the inner ends of the springs are equidistant and in the same plane as the center of gravity of the device to be protected. The device so protected may be mounted in any plane and subjected to shock and vibration in any direction. Effective snubbing action is obtained over a wide temperature range because the action of the all-metal spiral springs is unaffected by temperature variations. Four silicone-rubber grommets inserted in the spring supports act as stops under severe shock conditions. Electric connections are made from the movable base to the fixed terminal board by means of flexible wires. Test jacks and an equalizer potentiometer are mounted on the rigid base. Additional information on the mount may be obtained from the General Electric Company, Schenectady 5, N. Y.

Cantilever Beam Load Cell. An instrument for changing a mechanical force into a proportionate electric signal that is transmitted to an indicator or recorder for evaluation has been developed by the Automatic Temperature Control Company, Inc., 5200 Pulaski Avenue, Philadelphia 44, Pa. The load cell operates on the simple cantilever-beam principle, having one end of the beam fixed and applying force to be measured to the free end of the lever. The motion of the beam moves the armature in the linear transducer and an electric signal is generated. Successfully applied to testing machine applications, the beams have a maximum stress of less than 30,000 pounds per square inch. Up to four cells may be connected mechanically to a single platform for scale applications, and the cells electrically connected together in series so that the forces are added electrically. Dustproof, the load cell is accurate to ±0.25 per cent of full range. Complete information will be supplied by the manufacturer.

Explosion-Proof Heater. A 6,000-watt convection-type explosion-proof heater especially designed for use in atmospheres containing gasoline, petroleum, naptha, acetone, benzol, lacquer, solvent vapors, and natural gas has been announced by the Electromode Corporation. Approved by the Underwriters' Laboratories for use in class-1 group-D hazardous locations, the heaters are made in three models with

(*Continued on page 48A*)



...except for value!

Do nationally accepted standards for size, strength, and electrical performance put the basic quality of all station insulators on a par? If this is true, they would all last about the same length of time, and your own experience tells you they don't!

Standards apply to the "as manufactured" condition. They relate to the *first day* of an insulator's life, while what you actually got for your dollar is not measured until the *last day*. The better the insulator, the farther these days are apart.

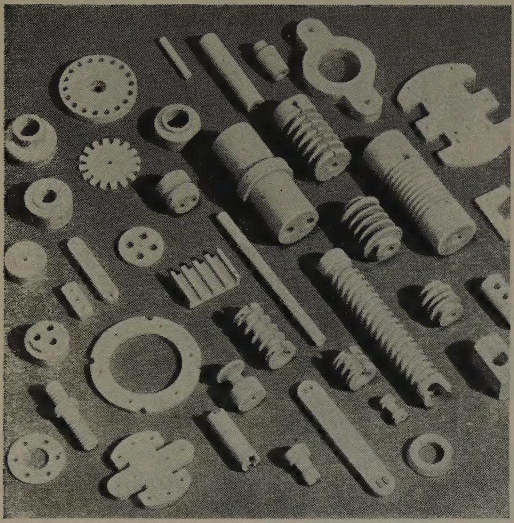
So far, thousands of O-B station insulators have put close to 35 years behind their first day. They are still giving satisfactory service with no hint of the last day's ultimate arrival. This performance *isn't* "standard" and can't be specified--except by putting "O-B" on your station insulator orders.

Ohio Brass
MANSFIELD OHIO, U. S. A.

4118

steatite, ceramic
& lava insulators

for
electrical
and
electronic
applications



Custom-molded, extruded or machined to close tolerances to meet your exact specifications. Prompt delivery at low cost on large or small orders. Over half a century of service is your guarantee of complete satisfaction.

FIND OUT TODAY. Illustrated bulletin with complete technical data will be sent on request.

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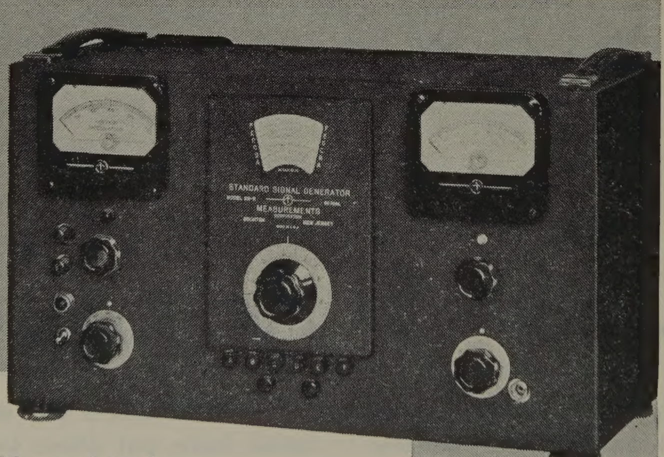
STANDARD SIGNAL GENERATOR

MODEL
65-B
RANGE
75 KC
to
30 MC



Individually Calibrated Scale

OUTPUT: Continuously variable, .1 microvolt to 2.2 volts.
OUTPUT IMPEDANCE: 5 ohms to .2 volt, rising to 15 ohms at 2.2 volts.
MODULATION: From zero to 100%. 400 cycles, 1000 cycles and provision for external modulation. Built-in, low distortion modulating amplifier.
POWER SUPPLY: 117 volts, 50-60 cycles, AC.
DIMENSIONS: 11" high, 20" long, 10¼" deep, overall.
WEIGHT: Approximately 50 lbs.

Catalog on request

MANUFACTURERS OF
Standard Signal Generators
Pulse Generators
FM Signal Generators
Square Wave Generators
Vacuum Tube Voltmeters
UHF Radio Noise & Field Strength Meters
Capacity Bridges
Megohm Meters
Phase Sequence Indicators
Television and FM Test Equipment

MEASUREMENTS CORPORATION
BOONTON NEW JERSEY

(Continued from page 46A)

ratings of 2,000, 4,000, and 6,000 watts. The complete safety of these heaters in dangerous locations is a result of a safety-grid heating element which consists of nickel chromium resistor wire, insulated and sheathed in a seamless metal tubing which is embedded in a 1-piece finned aluminum casting. This completely seals the element, eliminating fire, shock, and burn hazards. For detailed information, write Electromode Corporation, 45 Crouch Street, Rochester 3, N. Y.

Four-Channel Long-Haul Carrier. Either three or four high-quality telephone voice channels can be added to the physical circuit on long-haul toll lines by use of the new type *32E* Lenkurt Carrier telephone system. *32E* contains modulator-demodulator panels for the first three panels, the pilot regulator, and subordinate equipment. Space is available on the rear for fourth-channel subassemblies. This equipment utilizes the frequency spectrum from 3.3 to 35 kc for four channels, but can be operated with three channels on lines equipped with carrier systems above 30 kc. Four different frequency allocations are available to meet diverse system requirements. Automatic carrier synchronization can be provided for voice-frequency channels used for multiple-channel voice-frequency telegraph. Maximum terminal loop gains and maximum repeater gains of 45 decibels are achieved in the higher frequency branch, corresponding with operating ranges of about 200 miles of 104-mil copper line. Effective transmission is provided for an audio spectrum of 175 to 2,900 cycles per second per link. Between 300 and 2,700 cycles per second transmission variations are within 1 decibel. All-electronic, the regulator compensates for flat loss effects over a range of about 25 decibels while an adjustable network accommodates twist over about 5 decibles. Further information may be obtained from the Lenkurt Electric Company, 1105 County Road, San Carlos, Calif.

TRADE LITERATURE

RCA Reference Book. The Radio Corporation of America's Tube Department has issued the 1952 edition of its yearly reference book on RCA tubes, electronic components, test equipment, batteries, and miniature lamps. In addition, the book offers basic data on fundamentals of television and some helpful hints on television trouble-shooting, compiled by the Tube Department's television service specialist. Other features are a 56-page daily diary for 1952, calendars, and 16 pages of full-color maps. The RCA reference book may be obtained from all RCA distributors.

Connector Service Manual. A pocket-size, 32-page service manual has been published by the Cannon Electric Company, containing instructions for installa-

(Continued on page 54A)

The most complete line in the industry!

In the complete line of Westinghouse Electrical Instruments, you're sure to find the *right answer* to your measuring requirements. Moreover, you'll get a wider selection for specific applications, whether it be a-c or d-c current and voltage, single or polyphase circuits, watts or vars, frequency, power factor, synchroscopes, temperature indicators, ground detectors or position indicators.

For laboratories, production lines, power plants, field service, or military operations—whether the requirement is for recording or indicating—for portable or permanent application—Westinghouse Instruments give you lasting accuracy.

Meets A.S.A. Performance Requirements

Every Westinghouse Instrument is built to meet the rigid performance requirements of the American Standards Association. No more exacting guarantee of an instrument can be made.

Competent Application Assistance!

Westinghouse Instrument Application Engineers are available to help you in selecting and applying the proper instruments for your application. Simply call your nearest Westinghouse office.

For complete information on Westinghouse Instruments write for Booklet B-4696. Address: Westinghouse Electric Corporation, P. O. Box No. 868, Pittsburgh 30, Pennsylvania. J-40406

YOU CAN BE SURE.. IF IT'S
Westinghouse
INSTRUMENTS

A few years back, all switch and bus units were made with a short second shell which invited the possibility of cascading in stacks. That is, up until Pinco introduced the revolutionary new L 735 switch and bus stacking unit. With rugged porcelain, a larger second shell and an improved center design, this new unit showed far superior flashover performance and greatly reduced the tendency to cascade. It also provided added leakage protection and increased mechanical strength.

Today, this idea like many others pioneered by Pinco, is an accepted industry standard . . . further evidence that Pinco is constantly primed to keep abreast of industry requirements. So whether your insulator requirements are ordinary or extraordinary—the services of the entire Pinco organization are yours to command.

See Page 118 Pinco Catalog No. 49
for complete electrical and mechanical specifications.

The Porcelain Insulator Corporation
763 Main St., Lima, N. Y.

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Offices in Principal Cities

PINCO INSULATORS

Suspension Insulators . . . Switch and Bus Insulators . . . Distribution Clamps . . . Distribution Pin Types and Guy Strains . . . Transmission Line Fittings . . . Tree Insulators . . . Transformer and Circuit Breaker Bushings . . . One Piece and Multi-part High Voltage Pin Types . . . Suspension and Strain Clamps . . . Indoor Bus Support Porcelain . . . Lightning Arrester Porcelain.

(*Continued from page 48A*)

tion, inspection, disassembly, and reassembly operations on Cannon's new *AN*-"*M*" military specification and other resilient-insert connectors. The manual is available upon request to the Cannon Electric Company, Advertising Department, P. O. Box 75, Lincoln Heights Station, Los Angeles 31, Calif.

Station Planning. A new booklet published by the Television Transmitter Division of the Allen B. Du Mont Laboratories, Inc., 1000 Main Avenue, Clifton, N. J., offers a complete step-by-step outline for management and station engineers, and fully explains the facilities and function of all equipment necessary to the normal operation of a well-integrated television station. Entitled *Station Planning*, the booklet contains a complete breakdown for each equipment complement, explaining the actual equipment pieces and approximate costs of the various units incorporated in that group. *Station Planning* is available upon request to the Du Mont Laboratories.

Conservation Welding Problems. A 100-page "1951 Data File of Defense and Maintenance-Conservation Welding Problems" is offered by the Eutectic Welding Alloys Corporation, Department P, 40–40 172 Street, Flushing, N. Y.

Electronic Parts. The Milo Radio and Electronics Corporation, 200 Greenwich Street, New York 7, N. Y., has announced publication of their new 1,100-page 1952 general catalogue. Copies may be obtained by writing to the corporation on company letterhead, addressing Department *CA*.

Applications of Ferroxcube Ferrites. An engineering bulletin entitled "Introduction to the Application of 'Ferroxcube' " is available from the Ferroxcube Corporation of America, Advertising Department, Saugerties, N. Y.

Attachments and Accessories. The South Bend Lathe Works, 425 East Madison Street, South Bend 22, Ind., has issued a 35-page catalogue, number *5102*, on their attachments and accessories. It may be obtained upon request.

Allis-Chalmers Bulletins. The Allis-Chalmers Manufacturing Company has published three new bulletins: number *14B6143A*, "Rocking Contact Voltage Regulators"; number *03B7654*, "WA-Series Steam Turbine Generator Units"; and number *51B7225*, "Totally Enclosed Fan-Cooled and Non-Ventilated Motors." They are available from the company at 931 South 70th Street, Milwaukee, Wis.

Push-Pull Amplifier Circuit. The General Radio Company, 275 Massachusetts Avenue, Cambridge 39, Mass., has described a new push-pull amplifier circuit in their latest issue of the *General Radio Experimenter*, Volume 26, number 5. The magazine may be obtained from the company.